

ANNALS OF SURGERY

VOL. 123

MAY, 1946

No. 5



REPAIR OF SURFACE DEFECTS OF THE UPPER EXTREMITY*

MAJOR DARREL T. SHAW, M.C., A.U.S.,

CLEVELAND, OHIO

AND

MAJOR ROBERT L. PAYNE, JR., M.C., A.U.S.

NORFOLK, VIRGINIA

THE RECENT WAR has fostered the recognition of reconstructive surgery of the hand and upper extremity as a special problem. This is a result of the large number of hand casualties, with injuries involving skin, bone, joints, tendons and nerves, and the realization that the treatment of these injuries does not primarily fall into the field of any of the previously recognized specialties. Appreciation of this fact by the armed services has resulted in the formation of Hand Centers, where there has been a dissemination and correlation of knowledge of bone, nerve and tendon repair and of plastic surgery as it relates to the hand. This concept was formerly applied in only a few clinics throughout this country. The experience gained in handling a large number of hand injuries has resulted in improved technics and in some new procedures.

The repair of surface defects of the upper extremity demands a knowledge of the whole hand problem. Evaluation of the type of replacement requires a definite plan for the future care of the individual patients and a familiarity with the various plastic surgical technics involved. The operating surgeon should understand the underlying pathology and be capable of preparing for, or doing, whatever deep repair is necessary at the time of surface replacement. Not only is time saved but a better end-result is frequently obtained, for instance earlier nerve suture. Fewer operative stages with accompanying trauma and periods of joint immobilization result in better function, other factors being equal.

The hand and arm should be splinted in the position of function at the time of the original injury. Mobilization of the unaffected parts should be maintained, and complete mobilization obtained as early as healing will permit. Damaged or deinnervated muscles should be supported in a neutral position to prevent stretching and to prevent contracture of opposing muscles and

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.



FIG. 1.—Sensitive neuromatous nodule formed from divided digital nerve in amputation scar. Cure was obtained by resection of scar, neuroma and two centimeters of digital nerve.

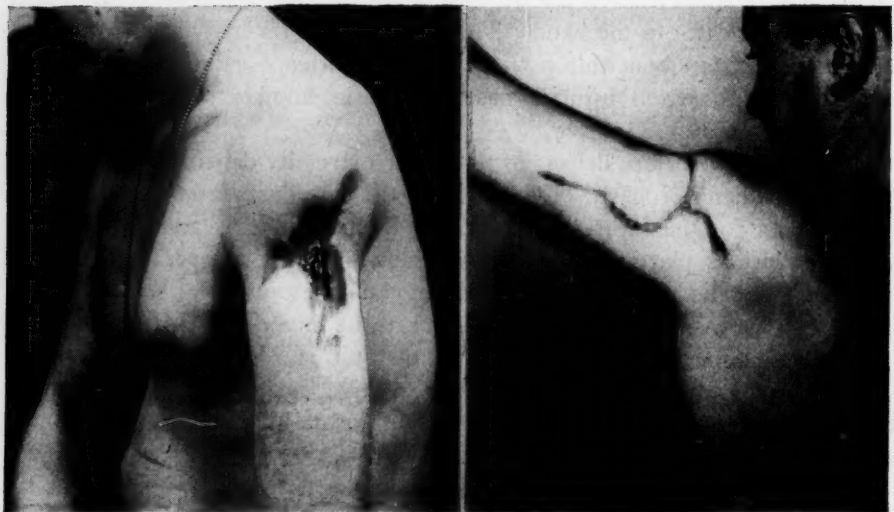


FIG. 2-A

FIG. 2-B

FIG. 2.—(A) Wound of shoulder with loss of skin and insertion of deltoid and resulting subluxation of shoulder and inability to abduct.

(B) Wound closed by undermining completely around the arm and over the shoulder. At the same time the deltoid insertion was sutured to the humerus. Postoperatively, the arm was maintained in abduction.

SURFACE DEFECTS OF UPPER EXTREMITY

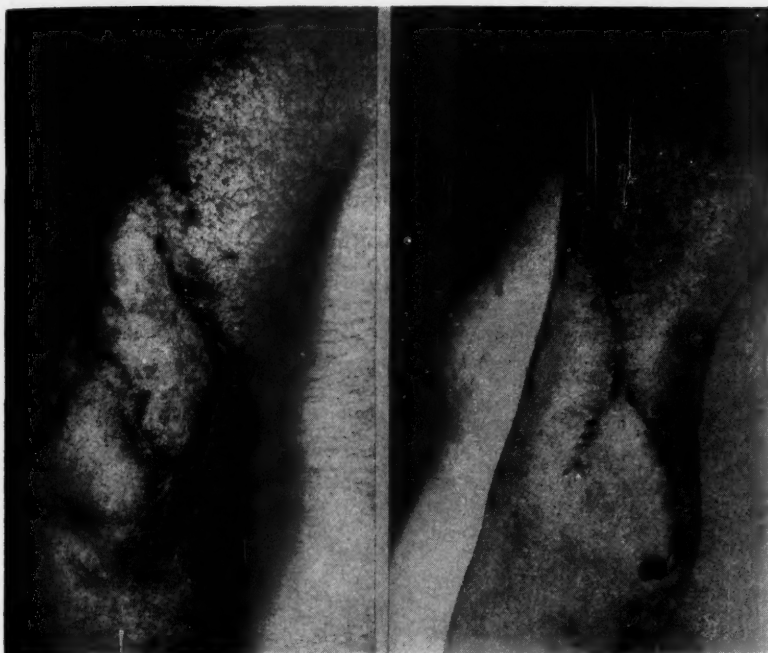


FIG. 3-A

FIG. 3-B

FIG. 3.—(A) Large defect of arm previously covered by split-thickness skin graft which was adherent to the humerus and painful.

(B) Ten days postoperative; following complete excision and closure by extensive undermining of skin and subcutaneous tissue. The edges were approximated under maximum tension by a continuous subcuticular stainless steel wire suture.



FIG. 4.—Postoperative view of rotation flap from posterior axilla used to cover shoulder defect.

tendons. Elevation and a mild pressure dressing on the damaged part prevents edema and circulatory congestion, leading to exudation, additional fibrosis and impaired function. Healing is promoted and less stiffening of the joints results. Open wounds should be kept clean and closed as early as possible by secondary suture, split-skin graft or flap. Selection of the method of closure is based on the final covering desired, though occasionally a thin split-skin graft may be applied as a temporary skin dressing. Clinical observation of wounds of the hand has shown progressive decrease of pain, swelling and joint stiffness as infection is controlled. Improvement is striking with the elimination of the open wound.

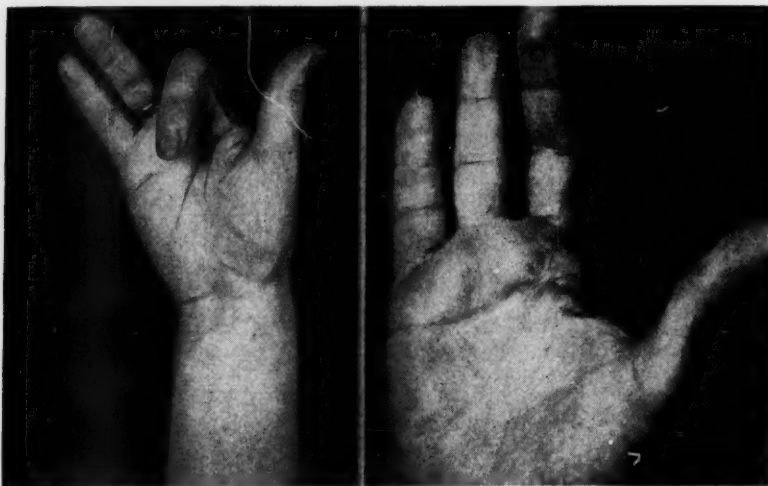


FIG. 5-A

FIG. 5-B

FIG. 5.—(A) Flexion contracture of middle finger with division of digital nerve supplying radial side of finger.

(B) Correction obtained by rotation flap and Z-plasty. A nerve graft from the amputated index finger was successfully used to obtain sensation.

The choice of the proper type of replacement depends on the amount of loss and on the requirements for contemplated surgery and ultimate function. In general, if the loss is superficial, adequate replacement can be obtained with a free skin graft, as best illustrated in burns. If the loss involves the deep structure, skin and subcutaneous tissue will be required. This may be as simple as a scar excision or as extensive as a pedicle graft. Most severe war injuries due to shell fragments fall into the latter category.

Complete scar excision is done at the time of replacement. This should include removal of foreign bodies, nonvital bone, and severely damaged tendons which cannot later be used. Wounds of the finger and hand resulting from missiles frequently are allowed to heal secondarily. Digital nerves, when divided, proliferate in these scars, sometimes forming deep, bulb-type neuromata and sometimes growing to the surface where they form smooth,

rounded and frequently reddened elevations varying from pin-point to three millimeters in diameter. These lesions are most frequently found on the ends of amputated fingers and are extremely sensitive to the slightest trauma. Cure is accomplished by removing the neuroma and scar and, if nerve suture is not indicated, a considerable length of the responsible nerve is removed and the end ligated.

Incisions and graft margins are placed so that they do not cross flexion creases and in general conform to Langer's lines of skin tension. Median longitudinal incisions are avoided even to the extent of removing normal skin. Midlateral incisions on the finger and incisions angulated to be parallel or oblique to tension lines and flexion creases are used.

Clean and complete healing is obtained postoperatively before mobilization is begun. When a contracture has been corrected surgically the part is splinted as near full correction as is consistent with optimal healing. Slow and gentle traction after healing completes the correction. This is preferable to expecting a wound to heal well while subjected to tension or motion. Certain less severe skin or deep scar contractures can be adequately corrected by traction alone. Complete hemostasis, a minimal amount of buried suture material and avoidance of trauma at the time of surgery assures better healing and minimizes formation of deep scar. Massive pressure dressings, evenly applied, prevent accumulation of blood and serum, prevent edema and venous congestion, coapt tissue surfaces and help provide immobilization. Fine stainless steel wire has proved very satisfactory for skin closure because it causes a minimal amount of reaction. This is particularly appreciated in a hand prone to excessive perspiration or with impaired circulation and slower healing.

Unhealed wounds in selected cases can be closed by secondary suture. Proper surgical preparation of the wound, including removal of all scar and granulation tissue, is the primary consideration. Foreign bodies, sinuses or sequestra are not necessarily contraindications for early and complete closure of wounds, especially with the control of virulent organisms by chemotherapeutic and antibiotic agents. A wound made surgically clean allows primary healing in the great majority of cases. It is our belief that drugs will not



FIG. 6.—Flap from amputated little finger used to cover defect on ulnar border of hand. (Courtesy Captain Samuel B. Fowler, M. C.).



FIG. 7-A



FIG. 7-B

FIG. 7.—(A) Band contracture at base of ring finger producing flexion deformity.
(B) Improvement after Z-plasty.

FIG. 8-A

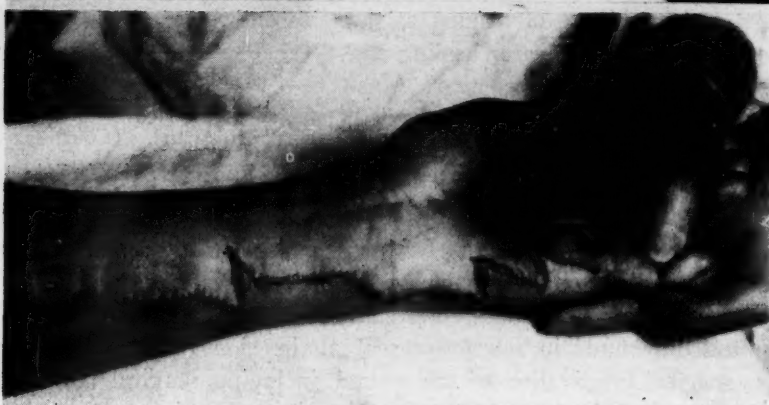


FIG. 8-B

FIG. 8.—(A) Broad, dense keloid with contracture involving wrist and little finger.
(B) Postoperative view following excision, undermining of edges and multiple Z-plasties.

FIG. 9-A



FIG. 9-B

FIG. 9.—(A) Flexion contracture of middle finger secondary to scar in palm.

(B) Extension and complete flexion obtained by excision of scar, tendon lysis and full-thickness graft.

FIG. 10-A



FIG. 10-B

FIG. 10.—(A) Severe flexion contracture of fingers and web between thumb and index finger secondary to burns.

(B) Early postoperative view of result obtained by relaxing incisions on palmar surface of fingers covered by "three-quarters-thickness" grafts from the medial side of the arm. The web has been deepened and the contracture relieved by Z-plasty and skin graft.

prevent infection if there is more than a minimal amount of nonvital tissue, hematoma, dead space or foreign material.

The method of choice in replacing defects is scar excision with closure by mobilization of the surrounding skin and subcutaneous tissue. This closes the defect with skin of the same type that has been lost and is simpler than most

FIG. 11-A



FIG. 11-B

FIG. 11.—(A) Keloid scar on dorsum of hand with limited flexion of thumb and fingers and flexion contracture of little finger. A thin split-graft had been applied.

(B) Full function obtained following excision of scar, release of contracture and application of thick split-graft.

other procedures. This method is often applicable to relatively large defects of the arm and forearm, less so in the hand because there is less skin for stretching without causing contracture. Extensive undermining, which may encircle the extremity, is supplemented by splitting the superficial fascia to obtain complete mobilization of the skin. A method for testing maximum stretching

of the skin is to pull the margin firmly and note whether the skin is mobile under the finger a distance from the edge. If it is, the skin is prevented from complete stretching by subcutaneous structures. Because the fibrous septa connecting the skin and deep fascia are better developed in the hand than on the arm and forearm, undermining is necessary for closure of even a small defect. Skin may be closed under considerable tension providing the tension is

FIG. 12-A

FIG. 12-B

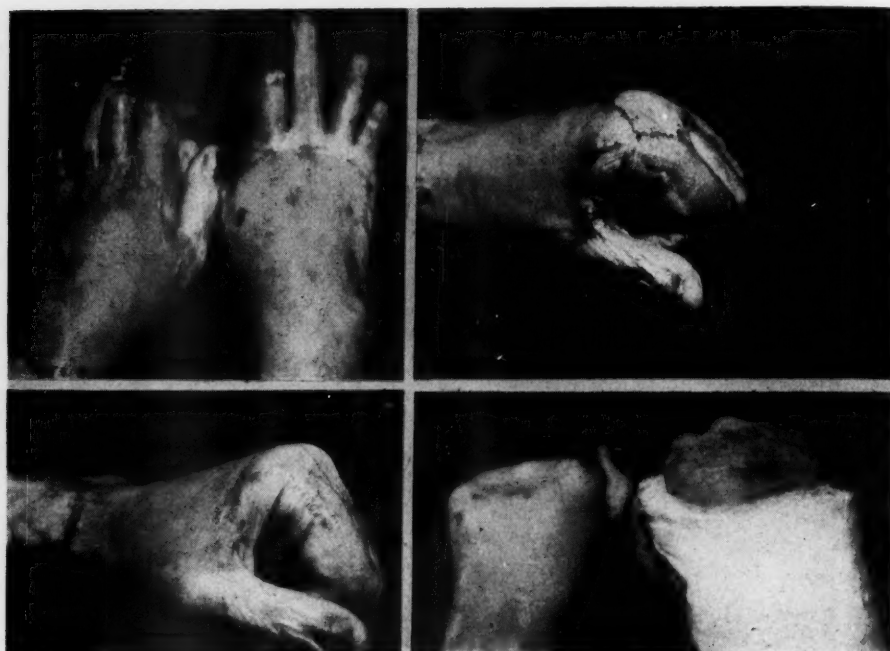


FIG. 12-C

FIG. 12-D

FIG. 12.—(A) Preoperative view of severe burn of hands with subluxation and inability to flex any of metacarpophalangeal joints. Grafts had been applied to the dorsum of the hands.

(B) Early postoperative view of graft over metacarpophalangeal joints of the left hand which was applied at the time of capsulotomy. A Z-plasty was also done to correct a band at the margin of the old graft which limited the motion of the thumb.

(C) Later postoperative view of the left hand showing complete flexion obtained by capsulotomy and skin graft.

(D) Left hand has been corrected. Fingers of right hand in traction to maintain flexion postoperatively following the same procedure.

carried by buried sutures in the dermal layer. The usual concept of the dangers of closing wounds under tension is based upon the use of cutaneous sutures to bring the edges together. Cuticular sutures under tension result in cutting, local impairment of circulation and necrosis with superimposed infection. This results in poor healing and frequently separation of the margins. Accurate approximation of the dermal layer by buried, nonabsorbable sutures (interrupted, inverted subcuticular or continuous subcuticular)

permits closure under maximum tension. Skin closed tightly will be found relaxed and fairly mobile at the first dressing if there is subcutaneous tissue and the skin is not bound down by scar. Additional relaxation takes place for several weeks. This phenomenon allows the closure of an occasional defect by multiple-stage scar excision. Initial stretching as well as subsequent relaxation is greater if the pull is perpendicular rather than parallel to Langer's lines.

Local flaps, in general, are useful for small defects and contractures on the hand and fingers. They offer the advantage of better sensation than skin grafts or pedicles from other parts of the body where sensation is not so well-developed. Rotation, or double pedicle flaps, from the dorsum are useful in the repair of amputated fingers when reamputation and shortening is undesirable. The loss of one side of a finger tip may be nicely corrected by shortening the nail, removal of a small amount of distal phalanx and rotating a flap. There have been no cases, in our experience, in which we have thought that it was indicated to apply a flap from the palm to the fingertip. Double pedicle flaps are useful on the arm or forearm where closure of a wound cannot be effected by undermining. In these cases a double pedicle flap is made by using a relaxing incision parallel to the original wound and free skin-grafting the defect produced. This provides a flap for the original deformity and places the graft on normal tissue.

When amputation of a finger is indicated, a large amount of skin becomes available for use on either the dorsum or the palm. The finger can be split in any vertical plane and the bone and tendons removed. The vessels are preserved. It is possible to use the finger as one flap or to rotate half in one direction and half in another, making one flap available for the palm and another for the dorsum. Finger skin thus used will usually remain viable to the distal joint. With this possible use in mind, fingers should be preserved at the time of extensive injury even though amputation will be indicated later.

Z-plastic procedures allow the release of contracture in one direction by utilizing tissue from the other direction. They are especially useful for band-type of contractures but can be used to relax broad areas under tension even utilizing scar tissue. The Z-plasty is indicated in the repair of finger webs, longitudinal scars of fingers and palm, band scars of the axilla and antecubital region and the contracted margins of grafts. Incisions crossing perpendicular to lines of tension will contract more than incisions parallel to



FIG. 13.—A direct abdominal flap applied to a large defect of the elbow.

tension lines. The Z-plasty prevents contracture in an incision crossing the lines of tension by substituting incisions which are oblique or parallel to the lines of tension. Longer scars may require multiple Z's. The Z-plasty is

FIG. 14-A



FIG. 14-B

FIG. 14.—(A) Adherent cicatrix of wrist with extensive loss of flexor tendons and median and ulnar nerves. The nerves were stretched as far distally as possible at the time of application of the flap.

(B) Result following application and division of flap.

mainly useful for release of surface contractures and does not usually supply a satisfactory bed for bone and tendon work.

Free skin grafts are indicated for surface replacements where local tissue is not available and where subcutaneous tissue does not need to be replaced. They are the method of choice for large superficial losses of skin, for instance burns and avulsed wounds. Thick-split grafts and full-thickness grafts are

better than thin-split grafts or small deep grafts because of less contracture. Full-thickness grafts contract very little and are movable over the underlying tissue shortly after the dressing is removed because of the presence of the deep

FIG. 15-A



FIG. 15-B

FIG. 15.—(A) Abdominal flap applied to antecubital region to correct severe flexion contracture involving biceps and including joint capsule. Extension was obtained at the time of application of the flap.

(B) Complete flexion is possible.

dermal layer which is normally mobile due to the loose arrangement of the fibrous meshwork and the presence of some fat and areolar tissue.

Thin grafts take more readily than thick grafts. Thin full-thickness grafts may be obtained for use on the hand from the lower abdomen, medial surface of the arm and anterior medial thigh. Thick-split grafts taken from these same areas, where the skin is thin, have much the same character as full-

thickness grafts and may largely replace them. Split grafts of the same thickness taken where the skin is thick, as on the back, split the derma where it is dense and less mobile and a graft with less pliability and more contracture results. Thus, the term "thick-split graft" is less descriptive of the functional result to be obtained than the term "three-quarter-thickness graft," as used

by Padgett. On a mobile base the pliability of the three-quarter-thickness skin graft, after several months, is equal to the full-thickness graft. The full-thickness graft is most useful on the palm and fingers.

Since the advent of the Padgett-Hood dermatome, excellent results have been obtained generally in resurfacing burned hands. Hypertrophic scars, or keloids, with contracture and a tendency to ulcerate are best completely replaced by a single large sheet of thick-split skin. If more than one graft is used the line of junction should be zig-zagged or placed to prevent contracture. The margins of the graft should be treated similarly, incising into, or even sacrificing, some normal tissue. The margins on a finger should



FIG. 16.—Direct abdominal flap applied to the dorsum of the hand. Arthroplasty was done at the time of application. Fingers are in traction following extensor tendon graft.

extend to the midlateral region. Better healing of the margin is obtained if the edge of the graft is sutured to the skin edge rather than overlapped. A good "take" is obtained by perfect hemostasis, adequate immobilization and pressure dressings. Massive fluffed-gauze dressings distribute pressure evenly and prevent pressure points. Small grafts are usually immobilized by tying interrupted sutures over a stent of gauze. Extensive deep repair is not usually possible under a free graft unless there is adequate soft-tissue underlying the graft to maintain the blood supply.

Stiffened metacarpophalangeal joints with subluxation and extension deformity are often found in severe burns of the hand. In severe or long standing cases they may not be corrected by manipulation at the time of grafting. Traction will not be effective before grafting because of the contracted scar and excess skin cannot be applied at the time of grafting unless the deformity is corrected. We have handled this problem by combining, as one procedure, capsulotomy, after the technic of Bunnell, with free skin grafting. Excision of the lateral ligaments does not always allow the joints to flex completely and manipulation to slide the proximal end of the phalanx over the metacarpal head is required. In some few cases even this maneuver must be supplemented by surgically releasing the contracted or adherent anterior capsule.

FIG. 17-A



FIG. 17-B

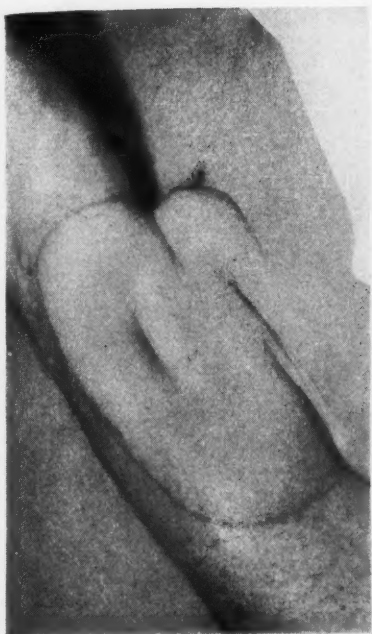


FIG. 17-C



FIG. 17-D



FIG. 17.—(A) Defect of forearm with loss of distal ulna, and one-half the shaft of the radius, with osteomyelitis. The sinus was opened, sequestra removed and the wound saucerized. A split-thickness skin graft was applied at the time.
(B) Skin graft has been removed and abdominal flap applied.
(C) The donor area and base of the flap, showing closure by split-skin graft.
(D) Final appearance of flap.

FIG. 18-A

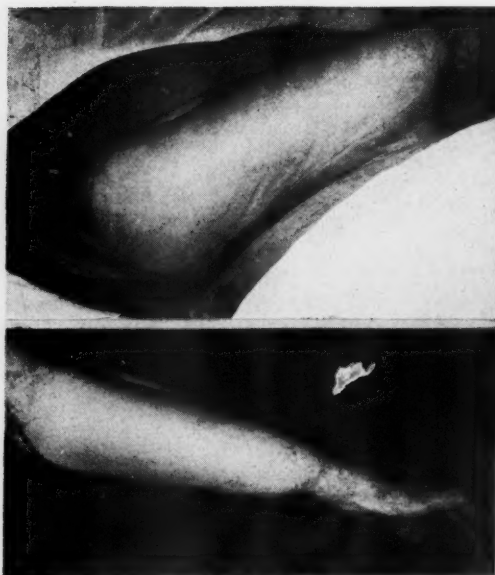


FIG. 18-B



FIG. 18-C

- FIG. 18.—(A) Large direct abdominal flap applied to the forearm from above the elbow to the wrist.
(B) Healed donor area on the lower chest and abdomen which was grafted when the flap was applied.
(C) Appearance of the flap following division.



FIG. 19-A



FIG. 19-B

- FIG. 19.—(A) Open wound of dorsum of hand with loss of extensor tendons and fracture of metacarpals.
(B) Wound closed by direct abdominal flap with donor area closed by suture. The base of the flap was grafted.



FIG. 20-A

FIG. 20.—(A)

Severe flexion contracture of the ring finger with loss of distal profundus tendon and capsulotomy of interphalangeal joints.

FIG. 20-B

(B) Contracture corrected by a direct abdominal flap and capsulotomy of interphalangeal joints.

FIG. 20-C

(C) Flexion was obtained by resuture of profundus tendon to distal phalanx.

Recently avulsed skin with insufficient blood supply to use as a flap can be replaced if it is trimmed down to a full-thickness graft, after the method of Farmer, or it may be glued to the dermatome and the skin split from the subcutaneous tissue at any desired level.

Pedicle grafts make possible the application of both skin and subcutaneous tissue to surface defects. They are classified into two main types—flaps and tubes. They serve to provide padding, improve contour, increase circulation to a part and to cover avascular areas where tendon, bone or open



FIG. 21-A

FIG. 21-B

FIG. 21.—(A) Recently avulsed wound of the thumb with exposed tip of the distal phalanx, a few days following injury.

(B) Final result after application of a direct abdominal flap. The nail and length of thumb were preserved.

joints are exposed. They provide tissue under and through which operative work on movable parts may be done. They may be used for closing deep open wounds instead of free grafts, thereby providing the final tissue covering. While free grafts may not be applied to a poorly nourished bed, for instance roentgen-ray burns, the pedicle may be used if the edges of the pedicle are attached to normal surrounding tissue. The margin of any pedicle should always be applied to tissue of normal vascularity and the pedicle should not be laid on a bed of dense scar tissue as it will develop circulation poorly and the attached surface will tend to contract, causing it to become firm, edematous and rounded.

Rarely, a pedicle can be utilized mainly to provide subcutaneous tissue

PLATE I

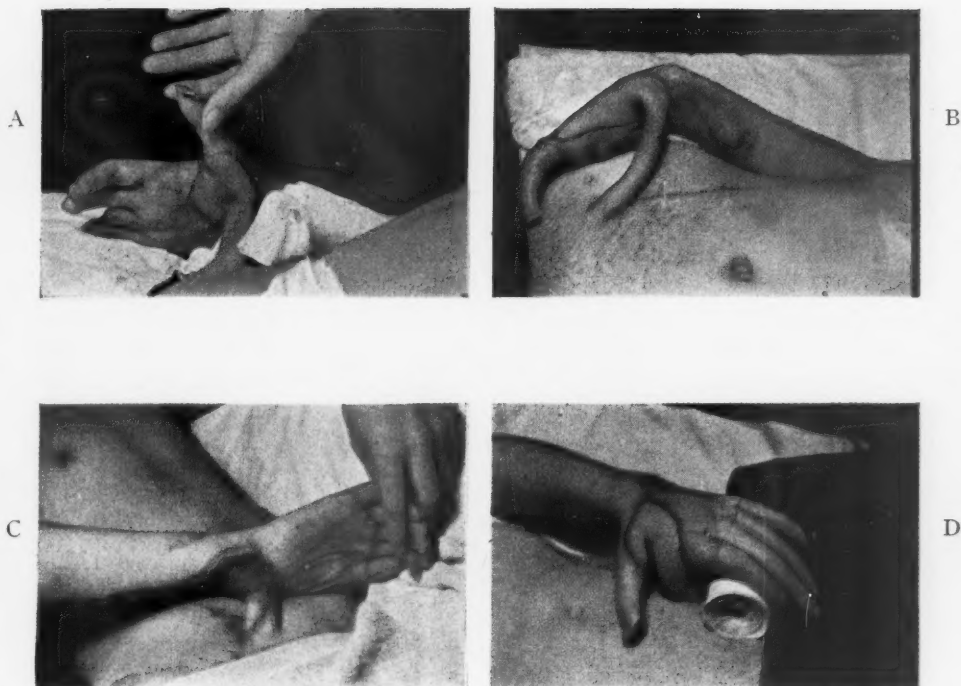
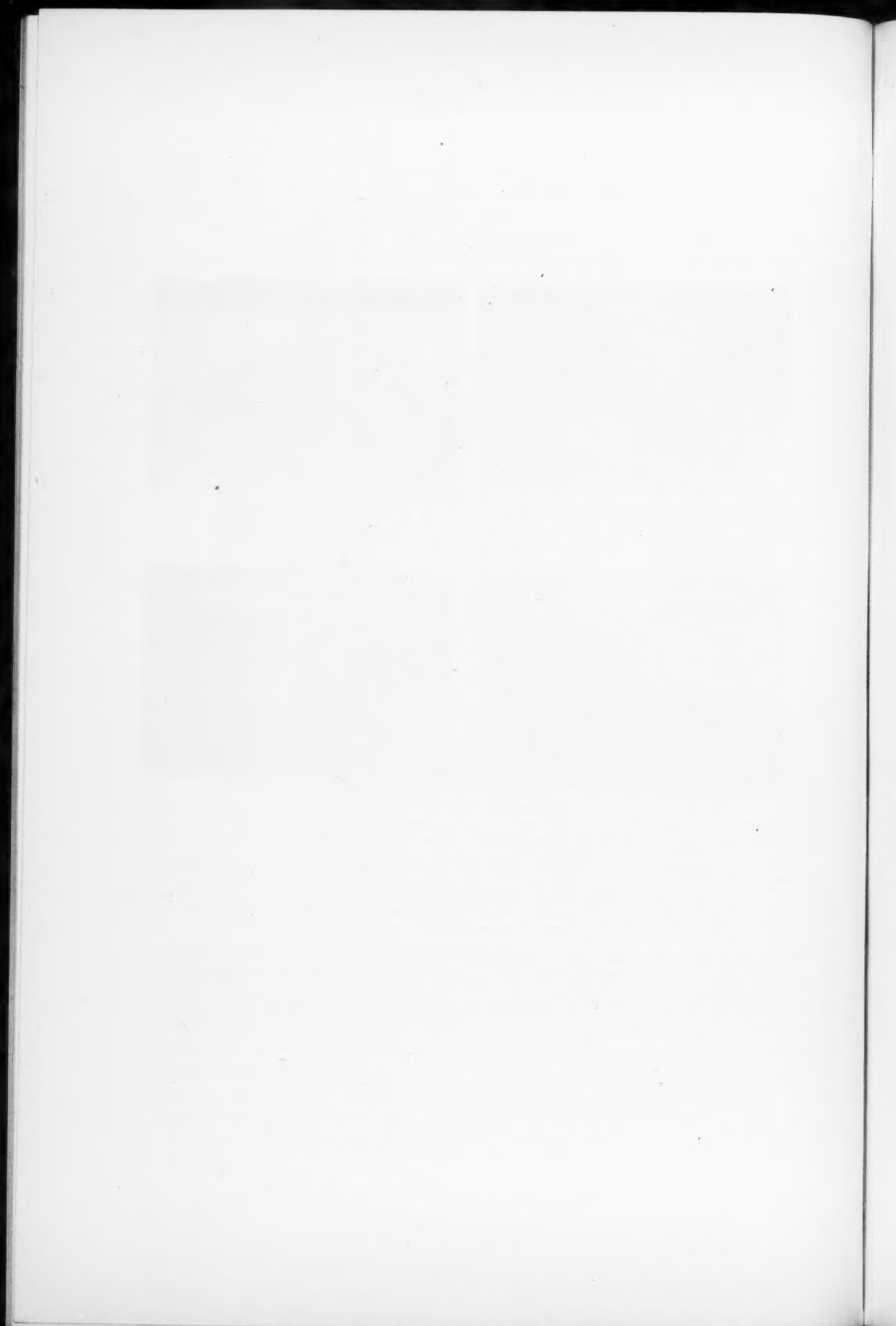


PLATE I.—(A) Double pedicle abdominal tube applied following excision of severe cicatrix of palm with extensive loss of thenar muscles, flexor tendons and nerves. The tube was applied to the wrist when divided.

(B) Application of a double pedicle tube to a severe injury of the hand and forearm.

(C) One-stage single pedicle abdominal tube applied to the wrist. At the time of application the ends of the divided median and ulnar nerves were overlapped by suture. At the time of division the nerves were sutured.

(D) One-stage single pedicle abdominal tube applied to web space to relieve contracture between the thumb and index finger. At the time of division the tube may be easily draped into the palm if required.



SURFACE DEFECTS OF UPPER EXTREMITY



FIG. 22-A

FIG. 22-B

FIG. 22.—(A) Shotgun injury with loss of index finger and injury of all flexor tendons in middle, ring and little fingers. (B) Direct abdominal flap has been applied to the base of palm and fingers. At the time of revision of the flap, ten No. 6 shot were removed from the profundus tendons, the sublimus tendons were removed and fatty areolar tissue was wrapped around the profundus tendons. Photograph shows almost complete flexion which was present ten weeks following operation.

FIG. 23-A

FIG. 23-B

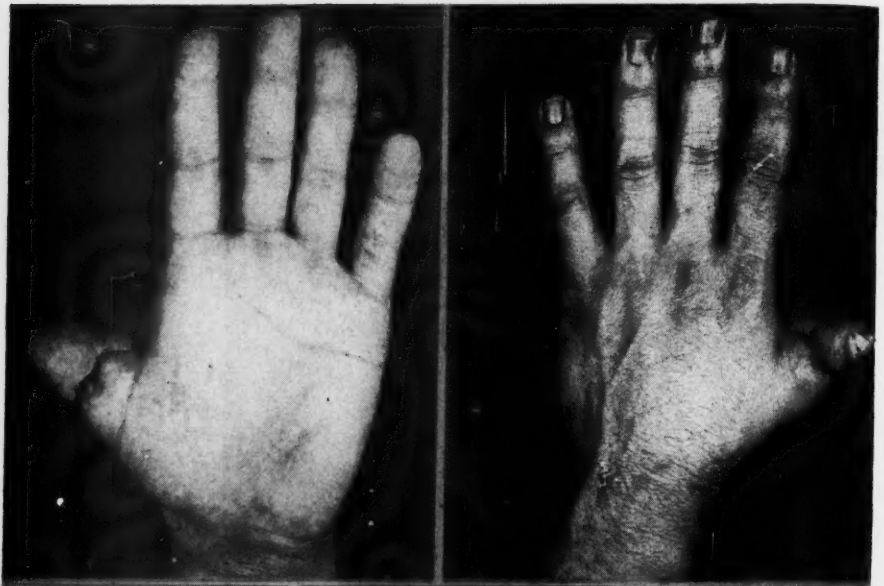


FIG. 23-C

FIG. 23-D

FIG. 23-E

FIG. 23.—(A and B) Deformity of thumb with loss of proximal phalanx. Sensation was present in the tip because of one remaining digital nerve.

(C) One-stage single pedicle abdominal tube applied after two-thirds of the attachment to the tip had been divided.

(D) Lengthening of thumb obtained by draping the tube completely around the thumb following division. One artery and the nerve were preserved. Sensation was retained.

(E) Early result following bone graft from metacarpal to distal phalanx.

FIG. 24-A



FIG. 24-B

FIG. 24.—(A) Extensive defect of hand with amputation of middle, ring and little fingers and marked ulnar deviation of index finger secondary to cicatricial contracture and fracture of metacarpal.

(B) Double pedicle tube has been applied and ulnar deviation of index finger corrected by excision of scar tissue.

and little or none of the skin used. In one instance of this kind subcutaneous tissue was placed beneath normal palmar skin to provide a bed for tendon graft and nerve suture.

The best donor site for flaps and tubes to be applied to the upper extremity is found on the abdomen or lower anterior thorax. Thin or thicker skin may be obtained with or without hair, and the donor defect may be closed or grafted with little deformity and no disability. Very large pedicles may be obtained and an excellent blood supply is assured if the arrangement of the



FIG. 25-A

FIG. 25-B

FIG. 25.—(A) Wound of thumb secondary to an electrical burn. The flexor pollicis longus tendon was lost. The proximal phalanx and the metacarpophalangeal joint were exposed.

(B) Wound was closed by application of direct abdominal flap. Joint motion was preserved in the metacarpophalangeal joint. A flexor tendon graft was done at the time the flap was revised.

vessels is kept in mind. This large area is accessible to the upper extremity, and combined with the adaptability of the hand to various positions a wide choice of location and direction of pedicle is provided. There is no indication for using the back or the buttocks as a donor area. The skin is thick, the position is unnatural and the scar may be painful. Cross-arm flaps have been used in a few cases but the procedure has been discarded because the type of skin does not compensate for the scar or the immobilization of both arms. Although the skin is thin and pliable it is little better than that found on the lower lateral abdomen.

Direct abdominal flaps are so-called because they are raised and applied

SURFACE DEFECTS OF UPPER EXTREMITY

directly to the recipient area. They may be open or closed, depending on whether or not the donor area or the base of the flap is left to granulate until the time of division. They offer a simple, quick method of replacement and usually are easily applied. Nearly every size or shape of defect found on the

FIG. 26-A



FIG. 26-B

FIG. 26.—(A) Severe wound of hand with flexion contracture of ring and little fingers and painful amputation stumps of thumb, index and middle fingers.

(B) The flexion contractures of the ring and little fingers, the web between the two and the cicatrix in the palm have been corrected by multiple Z-plasties and thick split-skin grafts. The amputation stumps of the thumb, index and middle fingers have been revised. The normal web between the thumb and index finger has been deepened by a Z-plasty to improve the grasp.

hand or forearm can be covered with reasonable care and planning. Two flaps may be applied to two different areas at the same time or a paddle may be delayed on the applied flap to be draped into position when it is detached.

In general, vertical flaps have a better blood supply because of the primarily vertical pattern of the superficial vessels between the groin and axilla. Only under extraordinary circumstances is it necessary to delay an abdominal flap prior to application.

Closure of the donor defect of the flap may be accomplished by split-skin grafting or suture following undermining. If it is grafted, the base of the flap may also be closed by extending the graft to the edge of the defect on the extremity. Where the donor area is closed by suture the base of the flap may be closed by grafting. Better healing of donor sites is usually obtained by suture than by grafting and the abdominal scar is more satisfactory. Quite large defects may be sutured.

In applications to the hand the wound of the open flap, even if kept surgically clean, leads to edema, stiffening of joints and pain. In our opinion, this constitutes an unhealed wound of the hand which delays or impairs return of function. Many flaps are applied to clean healed hands. It seems inexcusable to convert a healed area into an open wound when it can so easily be avoided. Relatively short additional time spent at the first operation saves dressing time and preserves the principle of keeping surgical incisions closed. In addition, the patient is more comfortable with a closed, cleaner wound which permits greater freedom of activity.

Double pedicle or pocket flaps are not necessary or desirable. The donor site cannot be closed as is often possible with a single pedicle flap and a clean well-healed graft is difficult to obtain. There is a more extensive wound to be closed at the time of division.

The usual double pedicle tubed-graft is mainly useful in cleanly carrying tissue to a distance. Because of the time required and hospitalization involved, it is not often indicated for the forearm and hand unless the defect is long and the direct flap is not easily applied. However, a well-healed pedicle does allow more flexibility and the application may be made under circumstances in which a direct flap would be most difficult, as for instance where there is limited pronation and supination in the forearm and lack of motion in the elbow. Sometimes it is desirable to establish a tube on the extremity for application at the time of subsequent surgery—for instance in relieving severe joint contractures and at the same time doing extensive surface replacement. The authors have favored vertical or slightly oblique tubes including the thoraco-epigastric vein, after the method of Webster. This is because the best blood supply is utilized in this manner and very large donor defects may be closed.

Paddles are seldom constructed on the ends of tubes because they usually require one or two additional operations for delay. Whenever possible the tube is originally planned to provide for the entire defect without a paddle.

One-stage single pedicle tubes have recently been described by the authors. They are usually based inferiorly to include the superficial circumflex iliac or superficial epigastric veins. They combine the cleanliness and mobility of the tube with the speed of the direct abdominal flap. They have been found quite useful and adaptable for the repair of defects on the hand and wrist.

At the time of application of a flap or tube injured deep structures are often exposed in conjunction with the removal of scar tissue and the opportunity is presented to complete certain repairs or to prepare the field for subsequent surgery. Certain definite limitations are imposed on the extent of this repair by position and immobilization, and it is not advisable to superimpose an involved reconstructive operation on an extensive surface replacement. However, nerves may be sutured or the ends approximated as much as possible to facilitate later suture. Fatty areolar tissue may be wrapped around adherent tendons either utilizing the fascia of the flap or free grafts. Surgical mobilization of joints by removal of scar, capsulotomy or arthroplasty may be done and sometimes is required before the potential defect is available for the reception of the flap. Removal or division of extensively scarred and adherent tendons which are limiting motion of joints or producing contractures is especially indicated.

A common problem presented in the war casualties which we have seen has been contracture between the first and second metacarpals, limiting the function of the thumb by preventing abduction and opposition. These injuries have combined loss of skin, deep scar, contracture of muscle and limited mobility of the first metacarpal on the greater multangular. Correction of the deformity requires excision of all deep scar tissue, section of the muscle sheaths, division of the insertion of the abductor pollicis tendon and division of the origin of the dorsal interosseous on the first metacarpal. In some instances it is necessary to incise the capsule of the first carpometacarpal joint. The relatively deep defect is covered by a pedicle flap. The one-stage single pedicle abdominal tube has been especially valuable for this replacement.

SUMMARY

Indications for different types of surface replacement and their use on the upper extremity have been discussed, with special reference to particular problems of the severely injured hand.

REFERENCES

- ¹ Blair, Vilray P.: The Influence of Mechanic Pressure on Wound Healing. *Illinois Medical Journal*, **46**, 249, October, 1924.
- ² Brown, James B., *et al.*: Direct Flap Repair of Defects of the Arm and Hand. *ANNALS OF SURGERY*, **122**, 706, October, 1945.
- ³ Bunnell, Sterling: *Surgery of the Hand*. Philadelphia, J. B. Lippincott Company, 1944.
- ⁴ Davis, John Staige, and Kitlowski, Edward A.: A Method of Tubed Flap Formation. *Southern Medical Journal*, **29**, 1169, December, 1936.
- ⁵ Farmer, Alfred W.: Treatment of Avulsed Skin Flaps. *ANNALS OF SURGERY*, **110**, 951, November, 1939.
- ⁶ Fowler, Samuel B.: Mobilization of Metacarpophalangeal Joints: Arthroplasty and Capsulotomy. Read before the American Academy of Orthopedic Surgeons, Chicago, January, 1946.
- ⁷ Gillies, Harold D.: Design of Direct Pedicle Flaps. *Brit. Med. Jour.*, **2**, 1108, December 3, 1932.
- ⁸ Gillies, Harold D.: Experiences with Tubed Pedicle Flaps. *Surg., Gynec. & Obst.*, **60**, 291, February, 1935.

- ⁹ Gillies, Harold D.: Practical Uses of Tubed Pedicle Flaps. *American Journal of Surgery*, **43**, 201, February, 1939.
- ¹⁰ Langer, K.: Zur Anatomie und Physiologie der Haut; I. Über die Spaltbarkeit der Cutis: Sitzungsberichte der Mathematisch. Naturwissenschaftler Classe der Kaiserlichen Akademie der Wissenschaften, Wien, XLIV Band. Abtheilung, Jahrgang 1861, Seite 19-64.
- ¹¹ Padgett, Earl C.: Calibrated Intermediate Skin Grafts. *Surg., Gynec. & Obst.*, **69**, 779, December, 1939.
- ¹² Shaw, Darrel T.: Open Abdominal Flaps for Repair of Surface Defects of the Upper Extremity. *Surg. Clin. N. A.*, **24**, 293, April, 1944.
- ¹³ Shaw, Darrel T., and Payne, Robert L., Jr.: One-stage Tubed Abdominal Flaps. Read before the American Society of Plastic and Reconstructive Surgery, New York, October 14, 1945. To be published in *Surg., Gynec. & Obst.*
- ¹⁴ Webster, Jerome P.: Thoraco-epigastric Tubed Pedicles. *Surg. Clin. N. A.*, **17**, 145, February, 1937.

EXPERIENCES WITH EARLY NERVE SURGERY IN PERIPHERAL NERVE INJURIES*

COL. R. GLEN SPURLING, M.C., A.U.S.,

AND

LIEUT. COL. BARNES WOODHALL, M.C., A.U.S.

IN WORLD WAR I approximately 3,500 peripheral nerve injuries were sustained by U. S. Army troops, of which approximately 1,000 seem to have been treated by neurorrhaphy.¹ The results of this surgical effort, due to lack of an adequately planned and organized program for the study of neural regeneration, were for the most part lost. There do exist, however, sufficient statistical data, based upon individual surgical experiences, to justify the conclusion that the surgery of peripheral nerve injuries in that war was productive of disappointing results.^{1, 2}

Under this stigma the surgery of peripheral nerve injuries was undertaken in World War II, and until the early spring of 1944 no coördinated program was established for their management. At this time two considerations stimulated the initiation of a gigantic clinical experiment in the early surgery of such injuries: (1) The certain expectation of large numbers of casualties; and (2) the demonstration that delayed wound closure, when employed as a fundamental surgical principle, was almost certain to prevent and control wound infection.³

A description of this program, a discussion of the neuropathologic principles upon which it was based, and certain interim and preliminary results which have flowed from it will be presented in this sequence. An attempt will also be made to correlate the lessons learned from this mass of material with the immediate and relevant problems of civilian traumatic neurosurgery.

Before proceeding to the presentation of this material, certain facts concerning the neurosurgery of World War I should be briefly outlined.¹ Most of the patients with peripheral nerve injuries sustained in that war were treated in specialized centers in the Zone of the Interior. Although the advantages of early operation were fully appreciated, definitive surgery was not as a rule performed until several months after the wounds had been sustained. For this postponement there were two reasons. The first was delay in evacuation, which was naturally very much slower in World War I than in World War II. The second, and even more important reason was the prevalence of wound infection. Platt,² in his excellent review of the remote results of nerve operations in World War I, pointed out that the vast majority of nerve injuries belonged in the "primary" class, being characterized by gross destruction, with immediate loss of anatomic continuity, but that wound infection was a potent secondary factor. "The fully-matured lesion as seen during an exploratory operation,"

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-7, 1945, Hot Springs, Virginia.

he stated, "represents a composite histologic picture, to which the primary injury, the effects of wound infection, and the attempts at spontaneous repair on the part of the nerve have all contributed."

In the same review Platt cites Frazier's views as typical of prevalent American opinion concerning the appropriate time for operation in peripheral nerve injuries. In general, it was the practice to defer operation until at least three months after the wound had healed. Since, however, regeneration had been known to occur spontaneously as late as six months after the injury, and in rare cases after an even longer period, Frazier believed it wise to defer operation until this time. Then, if there were no evidence of regeneration, or if regeneration had begun but had not progressed, or if neuritis were evident, operation was regarded as indicated.

The statistics presently available for World War II show that approximately 25,000 patients with peripheral nerve injuries, representing some 10.5 per cent of all battle casualties, reached the level of the General Hospital. Though the figures are necessarily incomplete at this time, to date 7,000 cases of end-to-end suture have been recorded in the Peripheral Nerve Registry, which was established in November, 1944, for the purpose of assessing the progress of these cases at regular intervals.⁴

The statistics which have just been cited show the magnitude of the problem of peripheral nerve surgery in World War II. The task of evaluating the end-results of therapy, that is, neural regeneration, is a problem equally pressing and important, but is not one which can be concluded within a short time. Five years, at least, must elapse before definitive statements can be made concerning many of the results of the management of peripheral nerve surgery in World War II, but the material already in hand is sufficiently comprehensive to warrant certain preliminary statements concerning the end-results to date.

THE PROGRAM FOR THE MANAGEMENT OF PERIPHERAL NERVE INJURIES

It is an axiom of military surgery in an Overseas Theater that elective procedures should be kept at a minimum, so that a pool of hospital beds will always be reserved for unpredictable emergency use. Since the repair of peripheral nerves is chiefly elective, and since casualties with major nerve injuries are for the most part never again fit for combat duty, it is apparent, from the military standpoint, that such patients should be evacuated to permanent hospital installations at the earliest possible moment. From the surgical standpoint, after measures have been taken to preserve the extremity and to prevent infection, the patients' own best interests also demand that they should be promptly transferred to installations in which elective nerve surgery can be done.

Uncomplicated peripheral nerve injuries do not merit a high evacuation priority, and for this and other reasons, a large number of patients with nerve injuries sustained in the North African campaign did not reach Neurosurgical centers until six months, or more, after they had been injured. Before the start of the European campaign a provisional program was formulated for the treatment of peripheral nerve injuries in Neurosurgical Centers established in

the United Kingdom. Details of the program became more definite as experience increased with the increasing flow of battle casualties. It was still necessary, however, for patients with such injuries to accept a relatively low evacuation priority, the highest priorities in the neurosurgical category being given to brain and spinal cord injuries. It soon became evident that even under optimum conditions of *triage* patients with peripheral nerve injuries were reaching the Neurosurgical Centers in the United Kingdom no earlier than 14 to 21 days after wounding, having in the interim passed through two or more General Hospitals which were serving as transit installations. Many of the patients, in spite of the retarded evacuation, arrived with soft-tissue wounds still unclosed, and the first concerted effort in the new program was to expedite early wound closure, so that nerve explorations, with neurorrhaphy if necessary, could be instituted promptly upon their arrival at the Neurosurgical Centers. This was accomplished by directives, circular letters, conferences, personal contacts, and similar means.

Soon after the institution of the program it became apparent that peripheral nerve injuries repaired three to four weeks after wounding and delayed wound closure presented fewer technical problems than when nerve suture was delayed for a period of months. Mobilization of the proximal and distal nerve segments was more readily accomplished at this time because wound fibrosis was minimal, the pathologic changes at the point of nerve severance were usually not extensive, and when joint flexion was necessary, this method of decreasing the nerve gap was not prejudiced by static joint fixation. The soundness of the plan of early nerve surgery is evident from two very striking facts,⁵ that the incidence of insurmountable nerve gaps in the cases operated upon by this plan was less than 1 per cent, and that primary wound healing, in marked variance to the World War I experience, occurred in over 98 per cent of the cases subjected to definitive nerve surgery.

The selection of cases for the performance of early nerve surgery overseas was dictated by a number of considerations, the chief of which, as already pointed out, was the administrative task of evacuation, based upon military exigencies. Patients with extensive soft-tissue wounds requiring plastic surgical procedures and those with severe associated lesions of other types were prepared for further evacuation without definitive nerve surgery. Those with severe infections of the long bones, for instance, were evacuated without delay. When evacuation of uncomplicated nerve injuries to the Zone of the Interior was delayed because of lack of facilities for evacuation, the waiting period was utilized for reparative nerve surgery; in no instance, however, was operation permitted to retard evacuation. To expedite this policy disposition board proceedings were completed as soon as the patients were admitted to the hospital.

Every surgeon who participated in the peripheral nerve suture program was instructed in the generally accepted principles of operative treatment and in the regimen of postoperative care. Particular stress was placed upon the following essential considerations:

1. The suture line must be free from tension, this result being accomplished by extensive dissection, with transplantation of the proximal and distal nerve segments if indicated, rather than by excessive or unphysiologic flexion of contiguous joints.

2. The proximal and distal nerve ends must be accurately trimmed until grossly normal nerve ends were visible.

3. The transected nerve ends must be approximated by a very carefully performed interrupted epineural suture. The use of a transneural or sling suture was left optimal with the surgeon.

4. Rigid hemostasis was mandatory and was to be accomplished without the use of a tourniquet unless required by an associated vascular injury.

5. Nerve lesions other than division were to be treated by strict conservatism.

Tantalum wire, 0.003-inch, swedged upon atraumatic needles, was recommended but not made mandatory; fine silk could be used if it were preferred. The wire suture material, however, was considered superior to other materials for a number of reasons. Experimental studies had shown it to be inert in human tissue, and even at the beginning of the program it was surmised that potential suture line disruption could be recognized early by roentgenologic studies of a radiopaque suture line. When the necessity of later evaluation of large numbers of patients submitted to nerve suture is borne in mind, the importance of this consideration is manifest. Preliminary surveys of the patients reported in this paper, as well as those operated upon in Centers in the Zone of the Interior,^{4, 6} have supported the validity of this technical advance.

A small cuff of 0.00025-inch tantalum foil was placed about the suture site in almost all the cases handled in the European Theater of Operations, though in one Center a plasma clot sheath was used. This variation was permitted because experimental studies suggested that this method was valuable, and a comparison between various methods of suture-line sheathing thus became possible.

Postoperative extension of flexed joints was started at the end of the second week and was completed by the end of the fifth week. Early extremity extension was permitted chiefly because wound fibrosis was minimal at this period after the initial injury. The need for reduction of the hospital days, contingent upon a constant demand for rapid evacuation to hospitals in the Zone of the Interior, also influenced the regimen of early extension. Neuro-pathologic studies⁴ have shown that suture line disruption sometimes occurs when this plan is practiced, but the incidence is no higher than is noted when nerve sutures are protected for longer periods of time.⁶

It was constantly emphasized to all the participants in the peripheral nerve surgery program that operation is but a single stage in the treatment of paralyzed extremities. In order to prevent temporarily denervated muscles from becoming irreparably atrophied and fibrosed, physical therapy, chiefly in the form of galvanic stimulation, was employed before and after operation. The clinical use of this special method of physical therapy was based upon well

documented experimental studies.^{7, 8} When plaster encasements were used for postoperative immobilization, particularly in cases with associated injuries of the long bones, windows were cut over the bellies of the paralyzed muscle groups and galvanic stimulation was begun the day after operation. Other postoperative measures included massage, active and passive joint movements, and the use of dry and moist heat. Attention was repeatedly directed to maintenance of the mobility of the hand, which was achieved by minimal splinting and by detailed instructions to the patient in the care of his own disability.

At the start of the peripheral nerve surgery program, operation was attempted only in cases uncomplicated by associated or concomitant injuries. As experience increased, combined bone and nerve cases were carefully admitted to the same program, and some 300 patients were operated upon by this plan within an average time of 42 days after wounding.⁵

*Results.*⁵—Of 6,245 battle casualties with major nerve injuries treated in General Hospitals of the United Kingdom between D-Day and V-E Day, approximately 11 months, 2,873, or 46 per cent, were operated upon within the period designated as "early." The remaining patients, for reasons of military necessity and for other reasons, were evacuated to the Zone of the Interior. The time-lapse between wounding and operation varied from an average of 28 days in the weeks immediately after D-Day to 42 days in the period of heaviest fighting before V-E Day. The average of 39 days for the whole group was well within the optimum limits for repair, and, on the whole, probably represents the shortest practical time within which definitive nerve surgery can be done upon a large group of casualties under conditions of warfare. Nerve suture was performed in 54 per cent of the cases; in the remainder of the group, the nerve trunk was found in continuity and only neurolysis was done. The surgical mortality was 0.03 per cent, the single fatality presumably being the result of a procaine reaction.

The high percentage of normal healing (more than 98 per cent) is convincing testimony to the wisdom of delaying nerve surgery for three to four weeks after initial débridement of the wound. This excellent record was achieved solely by the practice of initial débridement, delayed wound closure, and the application of modern chemotherapeutic methods as prerequisite to definitive nerve exploration.

THE PATHOLOGIC BASIS FOR THE SELECTION OF THE TIME FOR DEFINITIVE NERVE SURGERY

In contrast to the progressive intraneural pathologic changes which dictate in large part the upper level of the optimum time for nerve repair, the factors which contraindicate primary nerve surgery in war injuries are entirely technical and mechanical: (1) The suture of a divided peripheral nerve at the time of wound débridement is not feasible by any technical standards, nor is it compatible with the surgical principles of preservation of life or extremity, or of the prevention of infection, which must be dominant at this time. (2) It is not possible for the surgeon at this time to estimate the intraneural damage to nerve segments adjacent to the point of severance caused by the distribution of

force developed by the war missile. (3) Selective section of nerve ends prior to suture is impossible unless a large nerve gap is arbitrarily established. (4) Mobilization and transplantation procedures essential for restoring the nerve gap and delimiting suture line tension are surgically unsound for fear of infection. (5) While in cleanly lacerated or in small penetrating wounds immediate nerve suture might be carried out by flexion of contiguous joints, the results in cases in which nerve gap has been overcome by flexion alone are likely to be prejudiced both by joint contractures and by the adverse effect of postoperative stretch upon the suture line.⁹ Moreover, this method may not be applicable if the point of suture is distant from an articulating surface. (6) Finally, the epineurium of a freshly divided nerve is thin and friable, and lacks the tensile strength to hold sutures.

In spite of this array of arguments, surgical opinion is by no means unanimously in favor of delayed nerve suture. On the other hand, the case for this plan has been well stated by Seddon:⁹ ". . . the delayed operation (in war wounds of peripheral nerves) converts the suture from a procedure carried out under restriction into one in which the surgeon is free to do as he wishes. At Oxford, all the primary sutures compare unfavorably with early secondary sutures, and if I had the misfortune to suffer a nerve injury myself I would prefer the secondary operation." The results of this plan, as will be pointed out later, have fully justified its use.

The practice of delaying operation to wait for evidence of spontaneous regeneration is indefensible. In the interim irreversible pathologic changes occur in the form of progressive degenerative changes in the distal nerve trunk, nerve endings and distal articulations, which impair and eventually invalidate the functional results of axonal regeneration. Furthermore, there is considerable evidence that these alterations impair nerve regeneration adversely in direct ratio to the length of time between the injury and the attempt at definitive suture.

A description of the entire gamut of changes in all the tissues of a denervated extremity is too complex a task to undertake here, and the emphasis will be directed to the most important alteration, which occurs in the distal nerve segment.

The first evidence of changes leading eventually to deterioration of the distal nerve trunk throughout its entire extent is a slight fibrotic thickening of the epineurium, which occurs between 15 and 25 days after severance of the nerve. Within this period the epineurium first attains the tensile strength which facilitates nerve suture. As time passes, the distal trunk exhibits two types of tissue reaction. The first type may be summed up in a single word—fibrosis. The epineurium becomes thicker and more dense. Collagenous tissue spreads diffusely in the interfascicular spaces. The normal cross-section area of the fascicles is diminished as the result of an enveloping perineural fibrosis which may progress to practical obliteration of the fascicular masses. Although the entire cross-area of the distal nerve trunk diminishes in size, the atrophy of fascicles is compensated for by a relatively greater ratio of interfascicular

fibrosis. Simultaneously with the fibrotic changes described there may be seen an endoneurial fibrosis, which at times almost replaces the attenuated groups of atrophic tubules.

FIG. 1-A

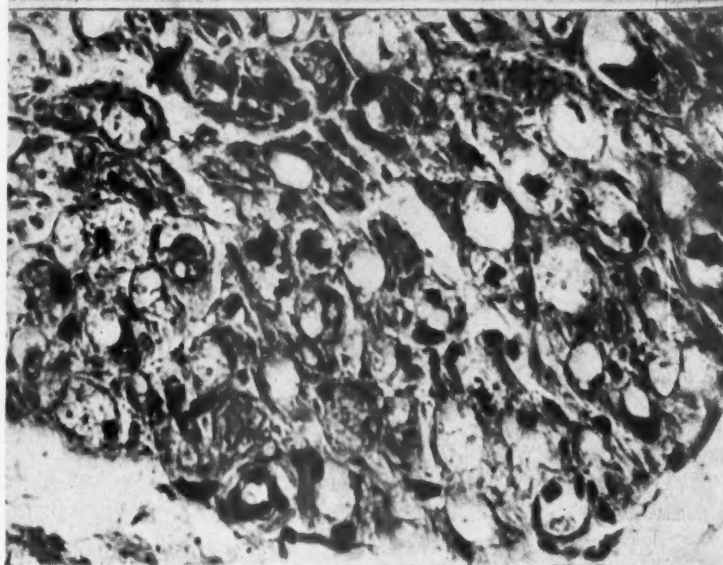
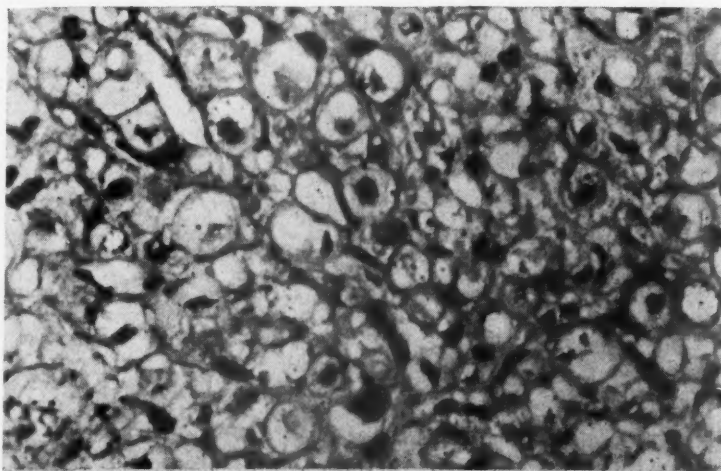


FIG. 1-B

FIG. 1.—(A) Cross-section of distal nerve segment, median nerve, seven days after nerve division, showing unshrunk tubules filled with degeneration products. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, ulnar nerve, one month after nerve division, showing unshrunk tubules, digestion chambers and lipophages. (Protargol and aniline blue, x600.)

The second major change in the distal trunk, which takes the form of tubule atrophy, can with some qualifications be readily associated with the lapse of time after wounding, although it is difficult to correlate exactly the fibrotic

FIG. 2-A

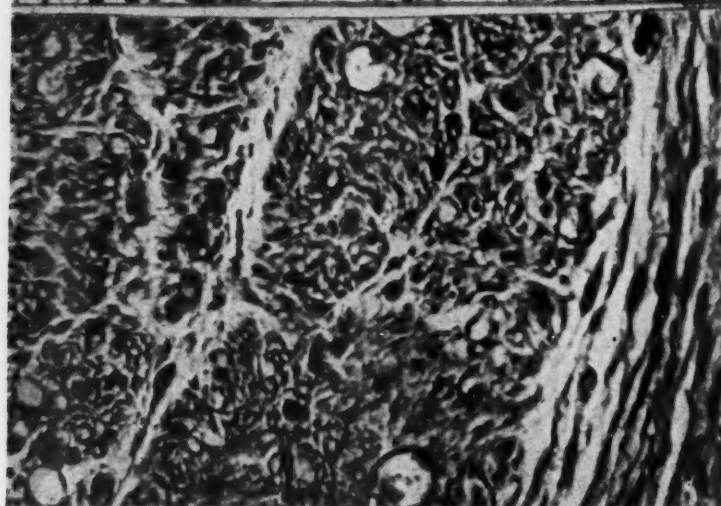
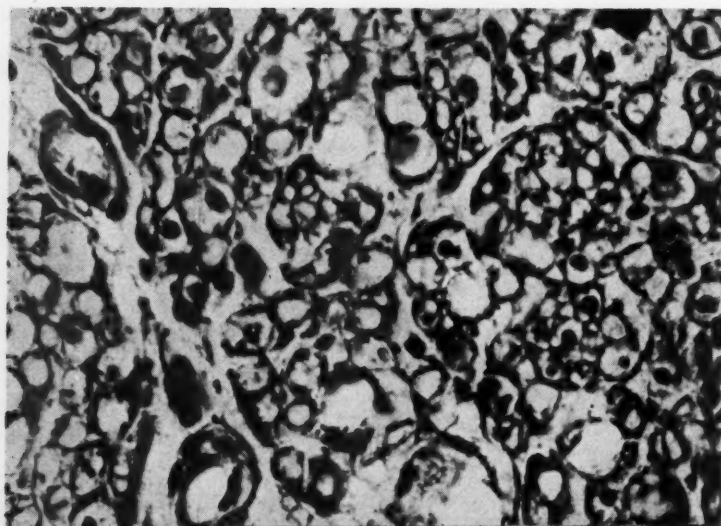


FIG. 2-B

FIG. 2.—(A) Cross-section of distal nerve segment, median nerve, two months after nerve division, showing unshrunk tubules with some variation in size. A few dots are seen against the circular neurolemmal sheaths, representing scattered regenerating fibers. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, ulnar nerve, two and one-half months after complete neuroma in continuity. The majority of the tubules have become atrophic and are being replaced by an endoneurial fibrosis. The perineurium is thickened. (Protargol and aniline blue, x600.)

PERIPHERAL NERVE INJURIES

FIG. 3-A

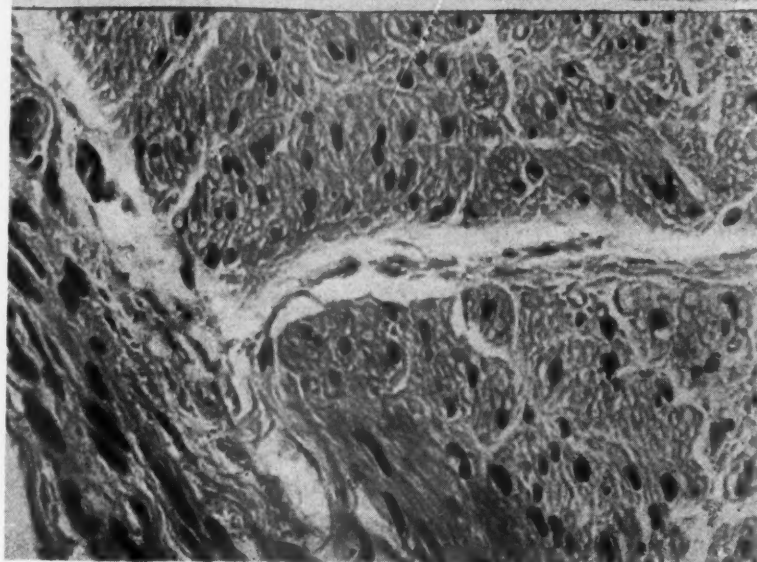
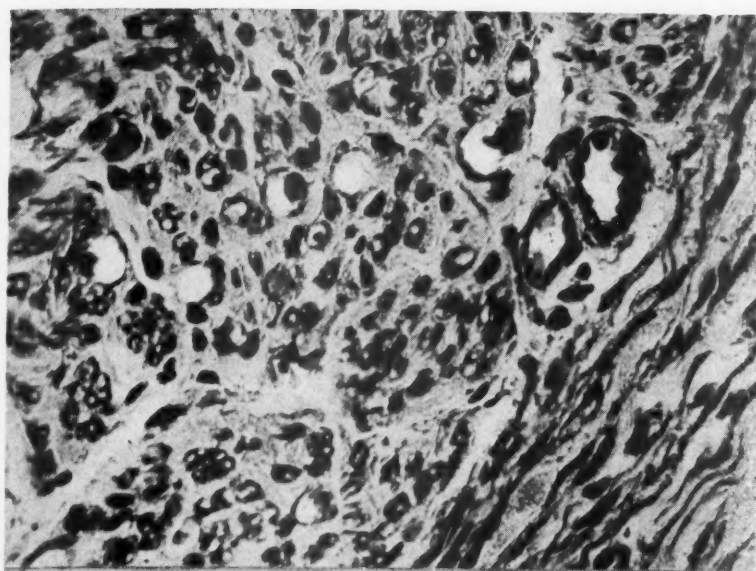


FIG. 3-B

FIG. 3.—(A) Cross-section of distal nerve segment, sciatic nerve, four and one-half months after complete neuroma in continuity. Only a few tubules remain unshrunk and endoneurial fibrosis is present. A few regenerating fibers are visible as small black dots about the periphery of the tubules. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, median nerve, five months after nerve division, showing advanced atrophy of tubules with marked endoneurial fibrosis. (Protargol and aniline blue, x600.)

FIG. 4-A

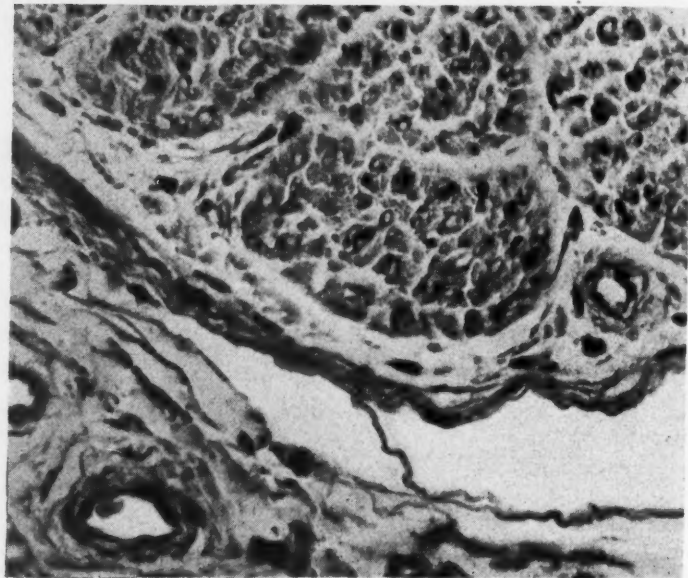
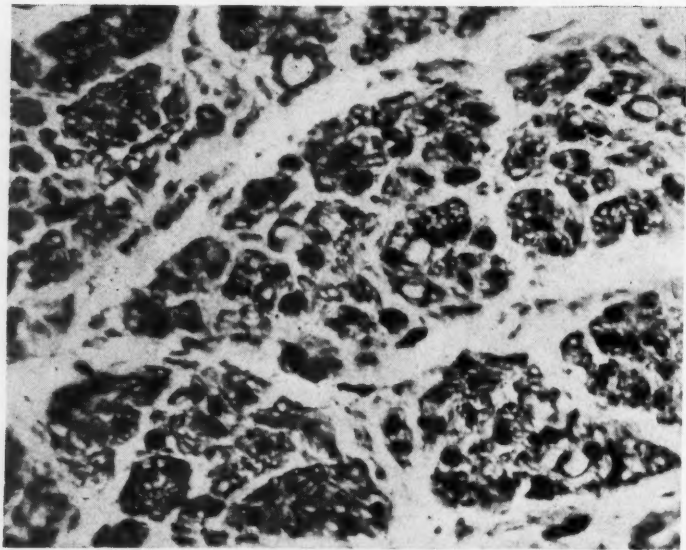


FIG. 4-B

FIG. 4.—(A) Cross-section of distal nerve segment, ulnar nerve, six and one-half months after nerve division, showing advanced tubular atrophy and endoneurial fibrosis. A few digestion chambers remain. (Protargol and aniline blue, x600.) (B) Cross-section of distal nerve segment, posterior tibial nerve, 14.5 months after nerve division, showing almost complete obliteration of the tubule lumina by a thick endoneurial fibrosis. There is some perivascular fibrosis. (Protargol and aniline blue, x600.)

PERIPHERAL NERVE INJURIES

changes first described with the passage of time. Progressive tubule atrophy in uncomplicated nerve injuries may vary in severity from case to case, but it remains a stable measure of the duration of distal segment deterioration unless it is even more adversely influenced by the factors of ischemia or traction. The normal maturation of regenerating nerve fibers depends to a large extent upon the number and volume of these tubular spaces. It will be noted in the groups of distal segment cross-sections, shown in Figures 1-4, that the tubule cross-section maintains its normal size until the end of the third month, after which rapid deterioration in size ensues. The volume of the tubular mass is replaced by a progressive endoneural fibrosis which (as shown in the 14.5-month specimen illustrated in Figure 4-A) may practically obliterate all evidence of tubule formation. Although the upper limit of potential functional regeneration cannot be fixed with certainty, it is a warrantable assumption, on the basis of this evidence, that it is within the three-month period following injury.

The pathologic basis for the selection of the optimum time for nerve repair can be determined with certainty only by comparison of nerve regeneration in a sufficient number of cases with the tissue changes present in individual cases. It is hoped that these data can be collected in the future through the Peripheral Nerve Registry and through the Peripheral Nerve Pathology Accession recently founded at the Army Medical Museum.

PRELIMINARY RESULTS OF EARLY NERVE SURGERY

A description of the Peripheral Nerve Registry, including the methods of recording essential data and of evaluating nerve regeneration, has previously been reported.⁴ To recapitulate, at the time of definitive nerve operation, initiating forms are forwarded by the operating surgeon to the central repository. The form includes basic identification data and a summary of the operative procedure. At three-month periods thereafter an assessment form is compiled for each patient, recording relevant electrodiagnostic findings, the distal advance of Tinel's sign, and motor and sensory regeneration according to a simple code. During the interim stage the assessment form can indicate only a trend toward regeneration or failure of regeneration. On the other hand, these official records form the only practical method of collecting the fundamental data necessary for the future study of more complete neural regeneration in large numbers of cases.

For the purposes of the present study, samples of cases of early nerve suture, ranging in number from 450 to 649, were chosen for review as the records appeared successively in the Registry. Since each study was of a specialized character, the totals vary somewhat for each phase of the investigation.

Causes of Failure.—In one group of 602 cases, a study was made of the causes of failure of nerve suture which occurred in 44 cases, the neuropathologic study being conducted at the Halloran General Hospital.

Among 89 primary nerve sutures performed on the day of wounding, or shortly thereafter, as a part of wound débridement, there were 20 failures, or 22.4 per cent (Table I). This high proportion of failures when primary nerve suture was done is to be compared with the 21 failures (5 per cent) which

occurred in 419 instances of nerve suture completed after delayed wound closure.

Neuropathologic study of the 20 failures after primary nerve suture revealed the following data:

In one case an error in tissue identification had been made.

In one case suture of a partial nerve severance resulted in a neuroma in continuity.

In two cases, although the procedure was recorded as "suture," the divided nerve ends had merely been coapted with a single sling suture.

In 16 other primary sutures, a suture line neuroma had developed in 11 and suture line disruption had occurred in five. In these five cases a severe wound infection played an important rôle in the destruction of the suture line and also retarded the performance of secondary neurorrhaphy. Factors underlying the

TABLE I

DISTRIBUTION OF FAILURES IN 602 CASES OF PERIPHERAL NERVE INJURY ACCORDING TO HOSPITAL INSTALLATIONS:
THE RELATION BETWEEN PRIMARY AND DELAYED NERVE SUTURE

Installation	Cases	Failures	Per Cent
Forward installations (primary suture).....	89	20	22.4
General hospitals (delayed suture).....	419	21	5.0
Installation unknown.....	94	3	
Total.....	602	44	7.3

development of suture line neuromas can only be surmised, but among them must be placed the inability of the surgeon to demarcate pathologic changes in freshly wounded nerve segments as well as postoperative tension on the suture line.

Neuropathologic study of the 21 failures of neural regeneration observed after delayed nerve suture revealed somewhat similar changes:

In one case an error in tissue identification had been made.

In one case regeneration was prevented by a circumferential wire sheathing-suture.

In one case the record did not make clear what procedure had been carried out at operation. A neuroma in continuity was found when late exploration was done.

In three cases nerve grafts had failed to take.

In five cases a suture site neuroma had developed.

In ten cases suture line disruption had occurred. In this group inadequate or accidental loss of postoperative immobilization seemed to play an important rôle.

Evaluation of Regeneration.—An analysis of 661 cases revealed that in 21.9 per cent definitive treatment had been carried out within 30 days after wounding, and in 73.9 per cent (the figures are cumulative), within 60 days; 91.8 per cent of all the cases were explored before the optimum time set for nerve repair had elapsed (Table II). The difference between these figures and those stated earlier for the individual survey of cases treated in Neurosurgical

PERIPHERAL NERVE INJURIES

Centers in the United Kingdom⁵ is explained by the fact that the Peripheral Nerve Registry covers cases of nerve suture from all Theaters of Operations.

In a group of 571 cases of early nerve suture, statistical sampling of assessments received at varying periods after operation disclosed a progressive

TABLE II

PROPORTIONATE DISTRIBUTION IN RESPECT TO TIME-INTERVAL BETWEEN WOUNDING AND DEFINITIVE NEUROSURGERY IN 661 CASES OF PERIPHERAL NERVE INJURY

Time-Interval (Days)	Actual Cases	Per Cent	Cumulative Cases	Per Cent
	63	9.5	63	9.5
6	22	3.3	85	12.8
12	13	2.0	98	14.8
18	16	2.4	114	17.2
24	31	4.7	145	21.9
30	37	5.6	182	27.5
36	66	10.0	248	37.5
42	74	11.2	322	48.7
48	68	10.3	390	59.0
54	50	7.6	440	66.6
60	48	7.3	488	73.9
66	26	3.9	514	77.8
72	21	3.2	535	81.0
78	34	5.1	569	86.1
84	26	3.9	595	90.0
90	12	1.8	607	91.8
120	33	5.0	640	96.8
150	10	1.5	650	98.3
180	1	0.2	651	98.5
Over 180	6	0.9	657	99.4
Unknown	4	0.6	661	100.0

TABLE III

TIME-INTERVAL BY MONTHLY ASSESSMENTS BETWEEN OPERATION AND FIRST APPEARANCE OF TINEL'S SIGN IN 571 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-Interval (Months)	Number of Total Assessments	Sign Present at Latest Assessment	Per Cent
1.9	57	38	66.0
2.9	73	53	72.0
3.9	157	133	84.0
4.9	83	61	73.0
5.9	47	39	83.0
6.9	68	59	86.0
7.9	25	21	84.0
8.9	22	19	89.0
9.9	21	20	90.0
10.9	3	3	100.0
11.9	3	3	100.0
12 and over	12	7	60.0

descent in Tinel's sign in a high proportion of patients (Table III). For example, in a group of 59 cases assessed 6.9 months after nerve suture, only nine failed to show this clinical phenomenon.

The trend toward motor and sensory regeneration was studied at various periods of time after nerve suture in 649 cases (Tables IV and V). Trends toward recovery in both respects improved progressively as time passed after

operation. For example, some evidence of motor regeneration was manifest in 33 of 166 cases assessed at 3.9 months after operation (approximately 20 per cent). In 28 cases assessed 8.9 months after suture, evidence of motor recovery was observed in 15 (approximately 54 per cent). Improving sensory status was observed in 32 of 165 cases assessed 3.9 months after operation (19.3 per cent). Similar improvement was observed in 17 of 27 cases assessed at 8.9 months after operation (63.3 per cent). Cumulative multiple assessment

TABLE IV

RATE OF SENSORY RECOVERY BASED ON MONTHLY POSTOPERATIVE ASSESSMENTS
IN 649 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-interval (Months)	Monthly Assessments	Monthly Assessments with Recovery	Per Cent
1.9	63	8	13.0
2.9	74	10	14.0
3.9	166	33	20.0
4.9	90	20	22.0
5.9	55	16	30.0
6.9	81	48	59.0
7.9	32	14	44.0
8.9	28	15	59.0
9.9	37	19	51.0
10.9	6	5	63.0
11.9	5	5	100.0
12 and over	12	9	75.0

TABLE V

RATE OF MOTOR RECOVERY BASED ON MONTHLY POSTOPERATIVE ASSESSMENTS
IN 649 CASES OF PERIPHERAL NERVE INJURY

Postoperative Time-interval (Months)	Monthly Assessments	Monthly Assessments with Recovery	Per Cent
1.9	61	7	11.0
2.9	76	9	12.0
3.9	165	32	19.0
4.9	91	20	22.0
5.9	56	24	43.0
6.9	80	48	60.0
7.9	32	18	59.0
8.9	27	17	63.0
9.9	36	27	75.0
10.0	6	6	100.0
11.9	5	5	100.0
12 and over	14	9	65.0

studies have not yet been completed in respect to either motor or sensory recovery.

In general, the statement can be made that the program of early nerve suture has demonstrated in the studies made to date a promising trend toward normal regeneration in most of the cases treated. The high incidence of failure in primary nerve suture has been clearly proved, and fully substantiates the directives issued during the war in the European Theater of Operations forbidding this procedure.

THE APPLICATION OF WARTIME EXPERIENCE TO CIVILIAN NEUROSURGERY

The question naturally arises at this time as to how the experience gained in the treatment of peripheral nerve injuries in wartime can be translated to civilian traumatic surgery. The wounding mechanisms in the two groups of cases are quite dissimilar. The disruptive, tearing force of a jagged fragment of metal with its pulsating cone of contiguous tissue destruction has no counterpart in the common civilian injuries in which cleanly lacerated wounds and closed injuries secondary to traction and to fracture or dislocation predominate.

The neurosurgical literature of World War I is replete with implications that although the treatment of peripheral nerve injuries was disappointing during the war, the treatment of civilian injuries of this type promised better results since infection would not play a rôle in the latter group. Infection played no rôle in the management of peripheral nerve injuries in World War II, and comparison with civilian injuries is, therefore, valid in this respect. Even with the factor of infection out of the picture, however, in civilian surgery neuropathologic studies suggest that the upper limit of the optimum time for nerve repair is in the neighborhood of three months following injury. Unless the course of expected spontaneous regeneration is checked, with due regard to the wounding mechanism, the rate of axonal regrowth, and the reinnervation of the proximal musculature, a policy of prolonged observation is never justified. This is particularly true when the wounding mechanism implies the possibility of complete nerve severance. In such a case as a simple fracture of the humerus with radial nerve paralysis, the minor procedure of early nerve exploration under local anesthesia is vastly preferable to delay that may impair the chance for full functional return.

The term "full functional return" must of course be used with qualifications based upon the association of extensive tissue or vascular damage, as well as with consideration of the specific function of the individual nerve. An analysis of the results of early nerve suture under the program used in the European Theater of Operations indicates that if a divided nerve is carefully repaired, if the wound is free from infection, and if the operation is done at the optimum time, early and progressive evidence of neural regeneration may be expected in contrast to the results of late nerve suture as practiced in World War I.¹

Analysis of the cases recorded in the Peripheral Nerve Registry⁴ indicates that a substantial percentage of unfavorable results follows primary nerve suture in war wounds. There is no factor present in the typical civilian type of nerve division, such as severance of the median nerve at the wrist, which would preclude the sequence of débridement, with or without delayed wound closure, followed by nerve suture *after* the initial wound is healed and *before* the optimum period for repair has passed. After wound healing has occurred, the surgeon is confronted with an elective and not an emergency procedure. He is not restricted, by the fear of potential infection, in the mobilization or transplantation of nerve segments if that should prove necessary. He is able to complete a technically facile suture through thickened epineurium without undue tension on the suture site and without forced joint flexion. Furthermore,

the accumulated experience of the war has shown that concomitant bone or tendon injuries are not contraindications to the deliberate and rational attack upon a severed nerve but that the sequence of therapy described is equally suited for the management of such combined injuries.

SUMMARY AND CONCLUSIONS

The policy of early nerve surgery (within three to six weeks after wounding) as practiced for peripheral nerve injuries in the European Theater of Operations is outlined. The neuropathologic reasons for the selection of this period as the optimum time for reparative neurosurgery are stated. Sample results of the policy are presented, together with evidence of the far less good results accruing from the practice of primary nerve suture. The lessons derived from this experience are applied to civilian traumatic neurosurgery.

REFERENCES

- ¹ Results of Peripheral Nerve Surgery, in The Medical Department of the United States Army in the World War. **11** (pt. 1), 1981, 1927, Government Printing Office, Washington, D. C.
- ² Platt, H., and Bristow, W. R.: The Remote Results of Operations for Injuries of the Peripheral Nerves. *Brit. J. Surg.*, **11**, 535, 1923-24.
- ³ Churchill, E. D.: The Surgical Management of the Wounded in the Mediterranean Theater at the Time of the Fall of Rome. *ANNALS OF SURGERY*, **120**, 269, 1944.
- ⁴ Woodhall, Barnes, and Lyons, W. R.: Peripheral Nerve Injuries. I. The Results of Early Nerve Suture: A Preliminary Report. *Surgery*, in Press.
- ⁵ Spurling, R. G.: The Management of Peripheral Nerve Injuries in the European Theater of Operations: With Special Reference to Early Nerve Surgery. *J. A. M. A.* in Press.
- ⁶ Whitcomb, B. B.: Personal communication.
- ⁷ Fischer, E.: Effect of Faradic and Galvanic Stimulation upon the Course of Atrophy in Denervated Skeletal Muscle. *Am. J. Physiol.*, **127**, 605, 1939.
- ⁸ Gutmann, E., and Guttmann, L.: Effect of Galvanic Exercise in Denervated and Reinnervated Muscles in Rabbits. *J. Neurol., Neurosurg., & Psychiat.*, **7**, 7, 1944.
- ⁹ Seddon, N. J.: The Early Management of Peripheral Nerve Injuries. *Practitioner*, **142**, 101, 1944.
- ¹⁰ Seddon, H. J., and Medawar, P. D.: Rate of Regeneration of Peripheral Nerves in Man. *J. Physiol.*, **102**, 191, 1943.

DISCUSSION.—DR. CLAUDE C. COLEMAN, Richmond, Va.: Doctor Spurling, as chief consultant in neurologic surgery for the Army, has had a very unique and exceptional opportunity to collect and correlate the observations on peripheral nerve injuries in World War II. His extensive experience in the treatment of these injuries at the Walter Reed Hospital has given him first hand information as to the important technical points in the suture of divided nerves.

The most important thing we have to do now is to find out just what surgery of peripheral nerve injuries will accomplish and to transfer the lessons learned in war surgery to the treatment of such conditions in civilian practice. I think it is a mistake to accept the statement that treatment of nerve injuries of warfare is applicable entirely to nerve lesions in civilian life. Doctor Spurling thinks the optimum time for suture of a divided nerve is three to four weeks after injury. I shall not go into any discussion as to the propriety of such delay in gunshot wounds of peripheral nerves, but in cases in which the nerve has been divided by a sharp instrument there should be no question of infection after mechanical cleansing and, as there is very little nerve tissue loss, a very limited resection of the nerve is required to permit adequate suture. If the primary

PERIPHERAL NERVE INJURIES

treatment of the wound is in the hands of those experienced in nerve surgery, then it would seem advisable to suture the nerve. If operation is delayed for three or four weeks there will be retraction of the nerve ends and neuroma formation, so that nerve tissue must be sacrificed to get the nerve ends approximated satisfactorily. This means more extensive resection of the nerve and in most cases there will be tension on the suture line. In gunshot wounds of nerves the explosive force of the missile causes damage to the segments and it may be difficult at the time of primary treatment of the wound to determine just how much of the nerve ends should be resected. I have always sutured the divided nerve at the time I did the primary treatment of a wound when the injury was caused by a knife or other sharp instrument, and this practice has been satisfactory.

The most common nerve injury requiring suture that I have seen in civilian practice is that about the wrist joint. Unfortunately, the primary treatment of these wounds is often conducted by an inexperienced member of a hospital resident staff, and it frequently happens that the end of the divided nerve is sutured to a tendon. It takes an experienced nerve surgeon to treat median and ulnar nerve lesions which are often associated with tendon injuries.

From the nerve surgery of World War II, we hope to get some information of real importance. A great deal of time has been devoted to the details of technic. I do not consider it important whether the suture material is tantalum wire or fine silk, but what I want to know most is, just how much functional recovery one may expect from nerve suture. We want criteria of recovery formulated, and the results of peripheral nerve surgery of World War II matched with this criteria. Notwithstanding the fact that nerve surgery in this country has been conducted by men of experience whose work has been excellent, I am afraid the final results still are not as good as we would like.

DR. JOSEPH E. J. KING, New York, N. Y.: I want to congratulate Doctor Spurling and Doctor Woodhall and the members of the Neurosurgical Staffs for the magnificent work they have done in the field of peripheral nerve surgery, not only with reference to the suture itself, but to all the measures which have been adopted in connection with peripheral nerve surgery. They have had the added advantages of splendid coöperation from top to bottom, with plenty of money to carry out the work. Their transportation service has been the best in the world and their work has been excellent.

Now, with reference to the last war, I wish to state again that good work was done by all the men who had the opportunity to work on a Neurosurgical Service. The cases, as a group, were operated upon considerably later than those of the present time, due mostly to delayed transportation and, in a number of cases, associated infection. Therefore, the final results should be better in this war than in the last. I personally know that the work at Cape May and Fox Hills, under the leadership of Dr. Charles Frazier, was well done and splendid records were kept. These records probably are covered with dust somewhere in the Surgeon General's office. Although Doctors Coleman, Stookey, and others, wrote splendid papers dealing with peripheral nerve surgery, it seems that these made little impression on the doctors in civilian practice, and a number of the younger men apparently knew very little about what went on before.

When Doctor Spurling used the word "stigma" I feel sure he was not referring to the surgery done by men such as Doctors Frazier, Coleman, Stookey, Elsberg, and others, and I doubt seriously if there has been much improvement in the actual technic of suture of peripheral nerves, or in the ability of the men performing these operations. On the Neurosurgical Services at Cape May and Fox Hills the number of patients would average between 500 and 600 most of the time, and the majority of these cases were peripheral nerve injuries. It is inconceivable that men of such caliber as those mentioned could handle so many cases and not do the work well. Various of my former associates and friends who are now doing nerve sutures in the Neurosurgic Services of the Army and Navy, have informed me that they know nothing new about nerve suture, and that the technic is just about the same, in their experience, as what was done in the last war.

COL. ELDRIDGE CAMPBELL, Albany, New York: These are the figures we have been eagerly awaiting, and I think, on the whole, they are most reassuring. Early in the war many wondered why it would not be possible to perform nerve suture at the time of

primary débridement. When the present program of wound management was put in effect in MTOUSA (?) this question pressed all the more strongly for answer. With Colonel Churchill's approval, primary nerve suture was carried out in quite a number of cases during the Italian campaign. Subsequently, it was largely abandoned for the following reasons: In the first place, with high velocity missile wounds—and I qualify all these statements with that—it was not always possible to predict how far back along the nerve trunk necrosis would extend. I think I might cite one case which falls into the category of which Doctor Coleman spoke. A soldier was admitted within four hours after receiving a small wound to his arm, in which the median nerve was divided. An excellent surgeon performed débridement of the wound; the nerve lay exposed "asking to be sutured." This was done, the wound was closed and the arm splinted, and he was transferred to a General Hospital a few miles away, and on the fourth day skin closure was carried out. The operator could not resist the temptation to open the deep fascia, and found the ends had not only separated by a centimeter but were softened for a good centimeter on each side.

Another thing, all wounds do not heal *per primam*, particularly in compound fractures, and if one does a suture at the time and something happens, just that much more trunk is sacrificed. In the third place, one frequently has to extend the wound very considerably above and below to effect an anastomosis without tension. Finally, many times one does not like to carry out a procedure which will take up a table for an hour, unless one has reasonable assurance that the patient will be more benefited then than he will later, by so doing. So the program in the Italian campaign was to close the wound, to stabilize the fracture, and then after the wound had solidly healed to perform nerve surgery four or five weeks after wounding.

Why not perform neurorrhaphy at the time of secondary suture? At that time the nerve ends were often edematous; in the interim the tissues are quite edematous, and while that might not make much difference, certainly there is nothing to lose by waiting a little longer.

Just one more point concerning the care of nerve ends at the time of primary débridement in high velocity wounds. I believe at the end of the last war it was suggested that nerve ends be brought together with a stitch at the time of primary débridement so they would not retract and would be easier to find. I had the opportunity to see some of these four or five weeks later. It seemed to me that the extent of the neuroma, the amount of swelling and the lengths which had to be resected were just as great and sometimes greater than in those in which this had not been done. I noted another thing, that divided ends lying free in the wound at the time of secondary closure four to ten days later, not infrequently were covered with fibrin and swollen, but at the point where they were protected by muscle, the fibrinous coat was much less marked. Therefore, it became the practice to cover exposed ends with muscle or some other tissue at the time of débridement. This is often impossible following makeshift nerve suture at primary débridement, for the nerve may thus be drawn into the wound in such a way that it cannot be covered.

These are some of the reasons why the results of primary suture of nerves divided by high velocity missiles have not been as good as those obtained when performed four to six weeks later.

MEDIASTINAL TUMORS*

REPORT OF CASES TREATED AT ARMY THORACIC SURGERY CENTERS IN THE UNITED STATES

COLONEL BRIAN BLADES, M.C.

ONE HUNDRED AND NINE PATIENTS have been operated upon for mediastinal tumors at Army Thoracic Surgery Centers in the United States** during a period of approximately three years. Numerically, the series seems meager when the potential patient population made up by millions of men and women in the military service is considered. Undoubtedly, the adoption of routine roentgenologic examination of the chest as a requirement for entrance to military service led to the detection, and immediate rejection, of many individuals with asymptomatic mediastinal tumors.

This report includes only cases in which either the clinical manifestations of an intrathoracic neoplasm or discovery of a mass in the mediastinum by roentgenologic examination after entrance on active duty resulted in surgical exploration of the chest. No attempt has been made to include all patients with mediastinal tumors treated in the United States Army or even in Thoracic Surgery Centers. Descriptions of neoplasms of lymphoid origin, namely, lymphosarcoma, Hodgkin's disease, lymphocytoma, *etc.*, have been omitted unless surgical intervention resulted from erroneous diagnosis.

Types of Mediastinal Tumors.—There were 94 benign and 15 malignant tumors in the group (Tables I and II).

BRONCHIOGENIC CYSTS

Twenty-three bronchiogenic cysts have been removed from the mediastinum. It is of interest that this relatively rare lesion was encountered so often. Hare¹ found no record of bronchiogenic cysts in the mediastinum in 600 cases of mediastinal tumors recorded prior to 1899. In 1937, Alford² reported seven cases. Three years later, Heuer and Andrus³ collected 25 cases from medical literature, and added one of their own. And, in 1945, Laipply⁴ found that 34 cases of mediastinal cysts of the bronchial type had been reported, and described another case, making a total of 35 cases. Even if allowance is made for incorrect classification of cysts of the mediastinum, and one assumes that some cysts of bronchiogenic origin have not been so classified, it becomes apparent that these lesions are relatively rare.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

** Baxter General Hospital, Spokane, Washington; Brooke General Hospital, San Antonio, Texas; Fitzsimons General Hospital, Denver, Colorado; Kennedy General Hospital, Memphis, Tennessee; and Walter Reed General Hospital, Washington, D. C.

The Chiefs of the Thoracic Surgery Sections at these hospitals are, respectively, Major Thomas B. Wiper, Major Donald L. Paulson, Colonel John B. Grow, Lieut. Colonel Richard H. Meade, Jr., and Colonel Brian Blades.

Location of Bronchiogenic Cysts of the Mediastinum.—The cysts may be located at almost any site along the tracheobronchial tree. In one case, not included in this series because the tumor was not in the mediastinum, a bronchiogenic cyst was located on the diaphragm, and there was no demonstrable connection between it and the lung or the mediastinum. When the mediastinum is involved, the most common location of the cyst is in the superior mediastinum near the tracheal bifurcation. The tumor may occupy either an anterior or posterior position. A patent lumen communicating with the trachea or bronchi could not be demonstrated in any of our cases.

TABLE I
BENIGN MEDIASTINAL TUMORS

Type of Tumor	[No. of Cases]
Bronchiogenic cysts.....	23
Dermoids and teratomas.....	14
Primary nerve tumors.....	29
Pericardial cysts.....	10
Thymomas.....	4
Lymph nodes*.....	4
Lipomas.....	3
Thyroid adenomas.....	2
Esophageal cyst.....	1
Tuberculomas.....	2
Sarcoid*.....	1
Fibroma.....	1
Total.....	94

* Biopsy of tissue, tumor not removed.

TABLE II
MALIGNANT MEDIASTINAL TUMORS*

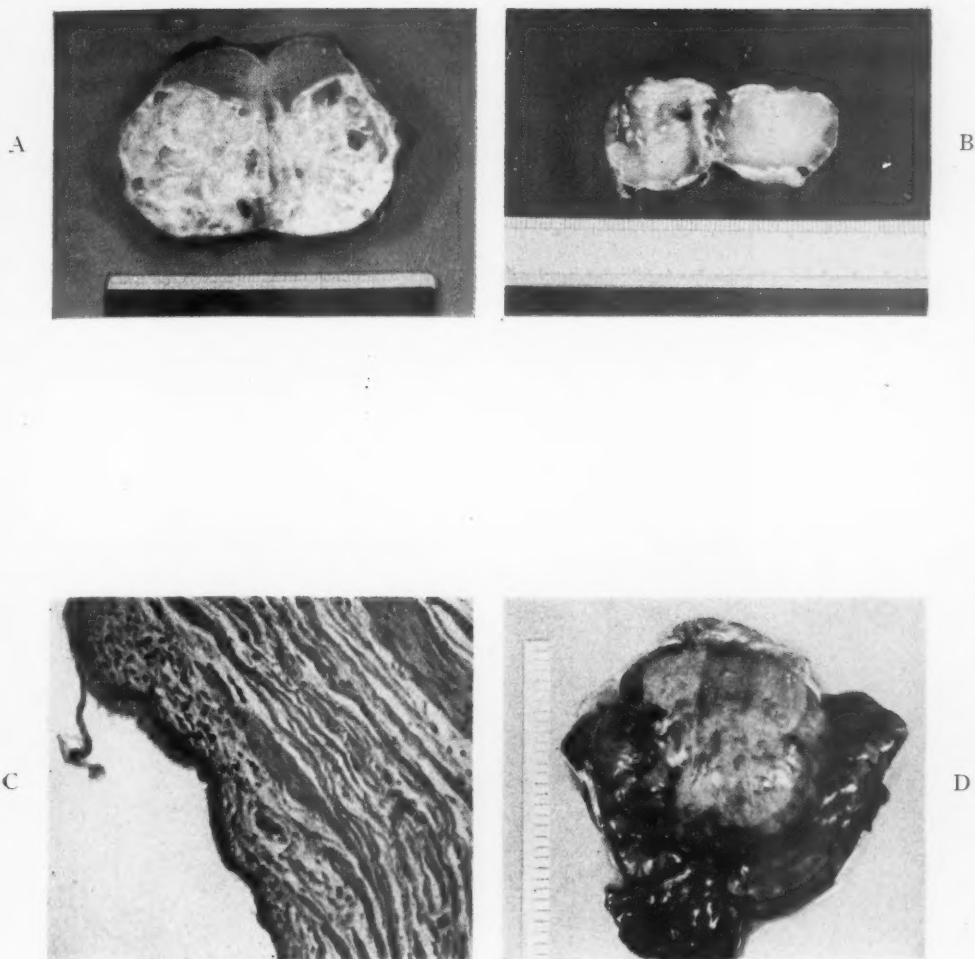
Type of Tumor	No. of Cases
Teratomas.....	6
Thymomas.....	2
Neurosarcoma.....	1
Lymphoblastomas.....	2
Hodgkin's disease.....	4
Total.....	15

* Extensive invasion of the tumor precluded even partial removal in all except three cases.

Clinical Manifestations.—Pain in the chest is the most common symptom of a bronchiogenic cyst. The pain is usually not severe, and its location is often substernal. Another common complaint is cough. Only two of the 23 cases considered in this report had clinical manifestations of intrathoracic disease. The mass was detected on roentgenologic examination in the remainder of the group.

Roentgenologic Examination.—An accurate preoperative diagnosis of a bronchiogenic cyst depends almost entirely on roentgenologic examination. Even with careful roentgenologic examination, the true nature of the lesion is

PLATE I



- (A) Photograph of semi-solid bronchiogenic cyst of the mediastinum.
- (B) Photograph of thin-walled bronchiogenic cyst filled with mucus.
- (C) Microscopic appearance of bronchiogenic cyst.
- (D) Photograph of tumor and right middle lobe after removal.



difficult to establish. On the frontal projection the mass may resemble a teratoid tumor or a primary nerve tumor (Fig. 1). The lateral roentgenogram is of more diagnostic significance, however, since the extreme posterior position common in most primary nerve tumors will not be duplicated by bronchiogenic cysts and, usually, the shadow of the mass on the lateral projection is not so distinct as is the case with teratoid tumors. Brown and Robbins⁵ have emphasized the importance of examination with the fluoroscope in establishing the diagnosis of a bronchiogenic cyst. Since most bronchiogenic cysts are attached to the trachea, the mass will move with the act of swallowing. This



FIG. 1.—Roentgenogram of bronchiogenic cyst.

can be demonstrated during fluoroscopy, and is of some significance as a diagnostic point. Roentgenograms made by the Potter-Bucky technic, visualization of the esophagus with barium sulfate to determine the relationship of the mass to the esophagus, delineation of the bronchial tree with radio-opaque oil, and other methods of roentgenologic diagnosis are sometimes useful.

Gross Appearance of Bronchiogenic Cysts.—Bronchiogenic cysts are round or ovoid masses, and may be located in any part of the mediastinum. They are usually attached to the carina or a bronchus by a stalk. It is sometimes very difficult to identify this attachment. The cysts may vary from thin-walled tumors filled with clear fluid to almost solid neoplasms (Plate I, A and B). Other descriptive terms which have been employed for these lesions are ciliated epithelial cysts and reduplication cysts of the respiratory tract.

All evidence suggests that bronchiogenic cysts are the result of developmental abnormalities, either from the pinching-off of a diverticulum of the foregut near the tracheal bud or a secondary development of the tracheal bud itself, resulting in an abnormal division of the tracheobronchial tree as growth proceeds. Similar theories have been suggested to explain the formation of esophageal, gastric and gastro-enteric cysts of the mediastinum. If these theories are accepted, it is understandable that occasionally a bronchiogenic cyst appears to be attached to the esophageal wall. Womack⁶ has suggested that available evidence indicates that bronchiogenic cysts represent "a regional disorganization in the vicinity of the developing trachea and foregut."

Microscopic Appearance.—Bronchiogenic cysts may contain any or all of the tissues which are normally present in the trachea and bronchi. The walls contain fibrous connective tissue and sometimes mucous glands, cartilage and smooth muscle. Stratified squamous epithelium or more typically ciliated pseudostratified epithelium forms the lining of the cyst. The fluid in the cyst may vary from clear, water-like liquid to viscid gelatinous material (Plate I, C).

Treatment.—Unless the age and general condition of the patient precludes a major operation, the proper treatment of bronchiogenic cysts is surgical extirpation. If the cyst is not infected, removal is usually easy. Technical difficulties are increased by the presence of infection, but this complication makes operative interference imperative.

The objection might be raised that if the tumor causes no symptoms, it should be left alone. There are several excellent reasons why the watchful waiting policy cannot be applied safely in the management of mediastinal tumors. The most important one is that it is impossible to make a positive diagnosis of any asymptomatic mediastinal tumor before the mass is removed. Many neoplasms of the mediastinum which have grave potentialities of malignant change resemble bronchiogenic cysts on roentgenologic examination, for example, the teratomas and thymic tumors. There is also the possibility of the cyst becoming infected or increasing in size, producing pressure symptoms. No reliable data concerning the incidence of malignant change in bronchiogenic cysts are available, but these lesions may be considered correctly cell rests. There is no reason, therefore, to believe that malignant changes could not occur. It is quite possible that highly malignant tumors which in the past have been catalogued under the somewhat ambiguous term—"carcinoma of the mediastinum,"—may have originated in bronchiogenic cysts. These neoplasms are at least first cousins of the teratoid tumors, both developmentally and histologically. The frequency of malignant change in dermoids and teratomas is well known.

DERMOIDS AND TERATOMAS OF THE MEDIASTINUM

Harrington^{7, 8} has simplified the terminology in discussing dermoids and teratomas of the mediastinum by employing the inclusive term—teratoid tumors. He chooses "teratoid" because most of these neoplasms contain elements of three germinal layers.

Twenty patients with teratoid tumors have been operated upon at Army

MEDIASTINAL TUMORS

Thoracic Surgery Centers. In 14 cases the tumor was benign. Far advanced malignant changes were evident in six cases.

Teratomas and dermoids of the mediastinum are relatively common tumors. More than 245 cases are recorded in medical literature. With the exception of tumors of lymphatic origin, which are usually not treated by surgical removal, the teratoid tumors are the most common neoplasms of the anterior mediastinum. Teratoid tumors usually produce sharp and obvious roentgenographic



FIG. 2.—Laminogram showing teeth in teratoma.

shadows which are easily detected. The relatively low incidence of teratoid tumors in members of the military service is easy to explain. Discovery of the tumor on roentgenograms of the chest made at the time of induction examinations resulted in immediate rejection.

Symptoms.—Cough and chest pain are the most common symptoms. In one of our cases the tumor had invaded the right middle lobe of the lung. The patient was admitted to the hospital for the treatment of hemoptysis.

Case 1.—A 28-year-old woman was admitted to the hospital for treatment of hemoptysis. The history revealed that she had coughed up blood over a period of 15 years, and for the past two or three years had occasionally coughed up large amounts of pus. Roent-

genograms of the chest revealed a mass in the right lower chest. Visualization of the bronchi of the right lung revealed some bronchiectasis of the right middle lobe and, on bronchoscopic examination, pus could be seen coming from the middle lobe bronchus.

A diagnosis of teratoma of the mediastinum, with erosion into the right middle lobe, was made. Exploratory thoracotomy revealed a teratoma of the anterior mediastinum attached to the right middle lobe. A right middle lobe lobectomy was performed and the tumor was removed with the lobe. The postoperative course was complicated by the development of suppurative pleuritis. The empyema healed after adequate drainage (Figs. 2 and 3 and Plate I, D).

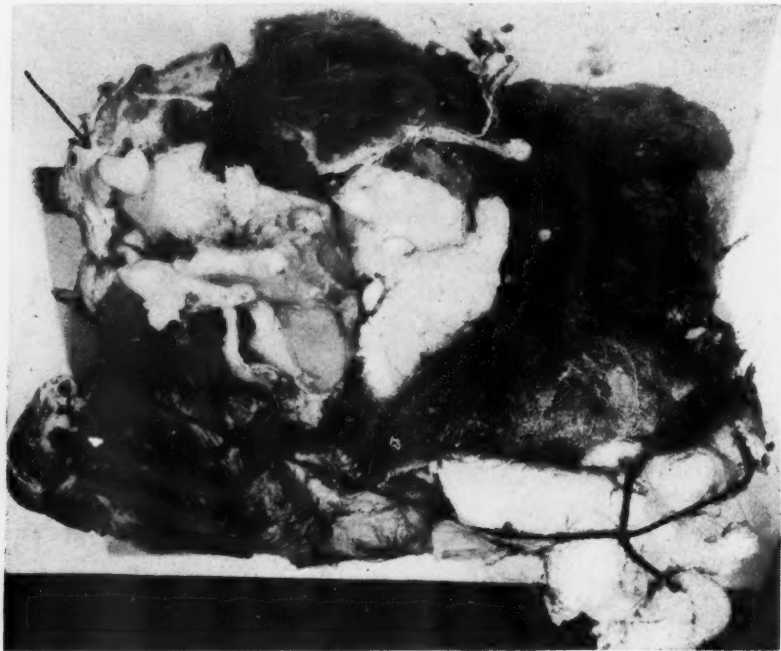


FIG. 3.—Photograph of tumor after section. Note teeth in tumor indicated by arrow.

Other clinical manifestations of teratoid tumors, including symptoms caused by pressure effects, namely, cough, dyspnea, and enlargement of the neck veins, are described in several excellent articles on dermoid cysts and teratomas of the mediastinum.

Roentgenologic Examination.—Unless teeth or bone are visible on the films, the exact diagnosis of the teratoid tumor cannot be made by roentgenologic examination. The characteristic anterior position of the mass is suggestive but not conclusive.

Location and Gross Characteristics of Mediastinal Teratoid Tumors.—Mediastinal dermoids and teratomas almost always occupy an anterior position. In fact, there are only three cases reported in which the mass was not in the anterior mediastinum. There is nothing particularly characteristic about their size or shape, and, as is the case with bronchiogenic cysts, the structure of

teratoid tumors may vary from thick-walled cysts containing fluid to solid tumors. Ectodermal derivatives, such as hair, skin or teeth, may form part of the tumor. Teratoid tumors are thought to take origin from cell rests. Bronchiogenic elements which are drawn into the thorax by the descent of the heart and diaphragm may account for the development of some of these neoplasms. Complex neoplasms with three embryonal layers, however, cannot be accounted for by this theory. Another popular hypothesis is that there is a second independent embryonal analage existing as a parasitic fetus *in fetu*. This theory would explain the complex teratoma while the monogerminal furnishes a satisfactory concept of the formation of a simple dermoid.

Microscopic Appearance.—Elements of the endoderm, ectoderm and mesoderm may be found in teratomas. Varying combinations of tissue from the digestive tract, respiratory system, thyroid or even thymus may be identified.

Treatment.—The treatment is surgical extirpation. Roentgenotherapy is of no value in the treatment of benign teratoid tumors and is probably equally ineffectual when malignant changes have occurred. The dangers of malignant degeneration are considerable. Laipply⁴ has reviewed the literature and found that 28 (11.4 per cent) of 245 cases of teratoid tumors were malignant. Heuer and Andrus³ report malignant changes in five of their 13 cases. Six of 20 tumors in this series had undergone malignant change and were hopelessly inoperable. The necessity for surgical extirpation of these neoplasms before they become malignant is obvious. Rusby,⁹ in his excellent article on dermoids and teratomas of the mediastinum, has described the various therapeutic endeavors which were employed before radical surgical excision was reasonably safe. He also emphasizes that collective data place the incidence of malignant change at 12.9 per cent and, that once the conversion from benignity to malignancy has taken place, the possibility of successful treatment is remote.

PRIMARY NERVE TUMORS

Twenty-nine benign neurogenic tumors of the mediastinum, including neurofibromas, ganglioneuromas, sympatheticoblastomas, *etc.*, have been removed successfully. One patient with a neurogenic sarcoma was operated upon, but invasion of surrounding structures precluded removal.

Neoplasms of neurogenic origin are by far the most common posterior mediastinal tumors. Kent and his coworkers¹⁰ were able to collect 105 cases in medical literature.

Clinical Manifestations.—Benign primary nerve tumors are usually asymptomatic. Occasionally involvement of certain nerves may cause pain; if the sympathetic chain is involved, Horner's syndrome may be evident. Too often, however, definite clinical manifestations of intrathoracic disease indicate malignant degeneration of the tumor.

Roentgenologic Examination.—The roentgenographic shadow of a primary nerve tumor may be round, spherical or lobulated. The typical extreme posterior position of the tumor is characteristic. Roentgenologic examination should include studies of the spine for bone erosion and evidence of so-called dumb-

bell tumor. The shadow on the roentgenogram is usually sharply circumscribed, both on frontal and lateral projections (Fig. 4 and Plate II, A and B).

Gross Appearance and Location.—The characteristic extreme posterior position of primary nerve tumors of the mediastinum has already been mentioned in the discussion of the roentgenologic examination. It is of interest that only two examples of primary nerve tumor in an anterior location have been recorded in medical literature.

If the neoplasm arises in the intervertebral foramina and extends both into the spinal canal and out into the posterior mediastinum, there will be an hour-

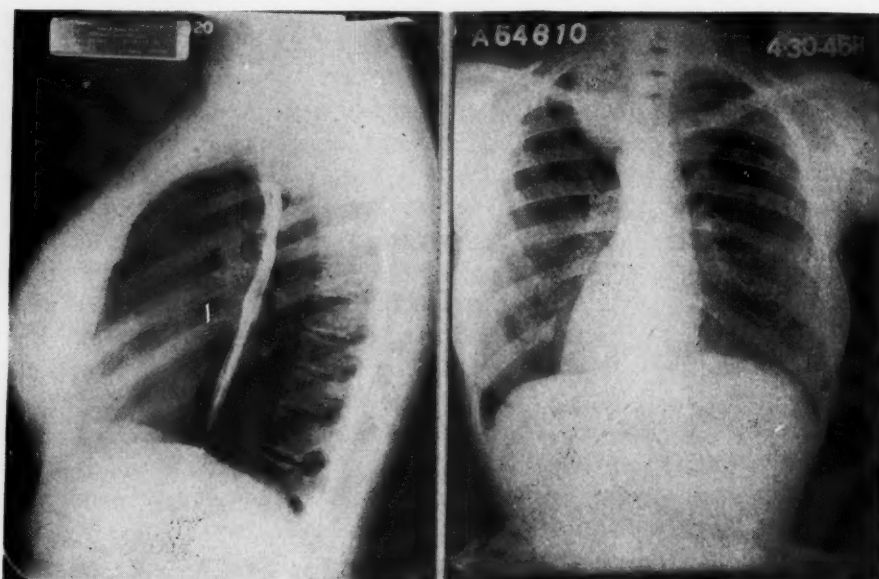


FIG. 4-A

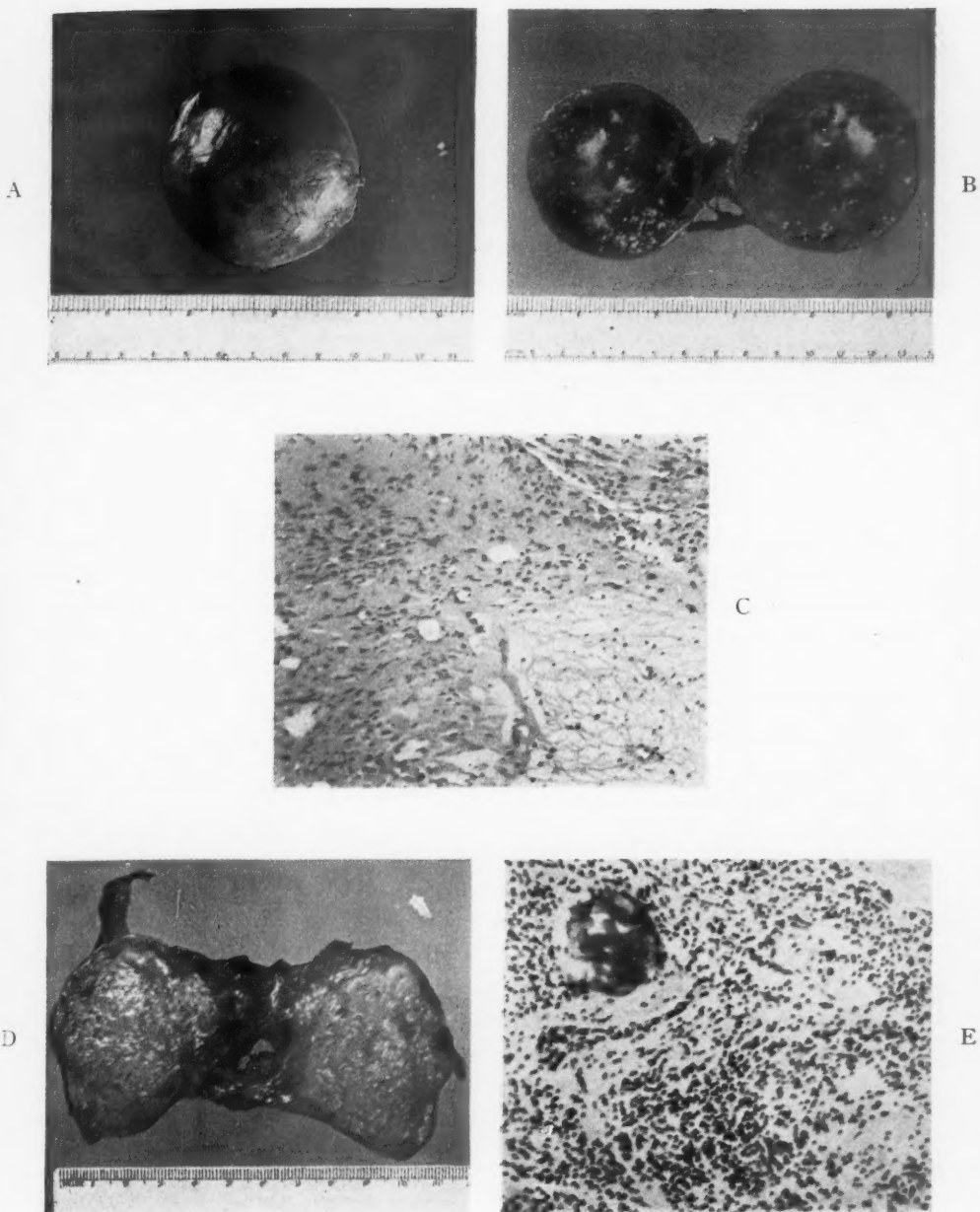
FIG. 4-B

FIG. 4.—Roentgenograms showing typical posterior position of primary nerve tumors of the mediastinum.

glass or dumb-bell configuration. The extension into the spinal canal is seldom evident on roentgenologic examination, and may even be difficult to detect when the tumor is exposed at operation. This possibility must always be given careful consideration. The sites of origin of the tumor are commonly from the intercostal and sympathetic nerves, although any nerve may be involved.

Microscopic Appearance.—There is wide variance in the microscopic appearance of primary nerve tumors. Preponderance of fibrous tissue in some has resulted in the descriptive term—ganglioneurofibroma. In others, numerous ganglion cells can be seen, and these tumors are usually called ganglioneuromas. Lack of differentiation with cellular reticulomyxomatous tissue may produce a microscopic appearance compatible with myxoid neuromas. Frank malignant degeneration is seen in neurofibrosarcomas. The degree of malignancy is difficult to determine, either on gross or microscopic examination. All

PLATE II



- (A & B) Photograph of neurofibroma of mediastinum after removal.
 (C) Microscopic appearance of neurofibroma of mediastinum.
 (D) Cut section of thymoma.
 (E) Microscopic appearance of thymoma. Note Hassall's corpuscle.



MEDIASTINAL TUMORS

primary nerve tumors of the mediastinum have a tendency to recur with increasing malignant characteristics if incompletely excised (Plate II, C).

Treatment.—Kent, et al.,¹⁰ have reviewed the medical literature and studied the cases of neurogenic tumors of the chest seen at Graham's Clinic, in St. Louis. They found that 37 per cent of reported primary nerve tumors of the thorax had undergone malignant change. Forty-one per cent of the cases of primary nerve tumor of the chest seen at the Barnes Hospital, St. Louis, were malignant. Even if one assumes that a large surgical center would attract more difficult and complicated cases and that there has been a tendency to report malignant and complicated cases, it is apparent that primary nerve tumors are dangerous. Once malignant degeneration has occurred, the prognosis is grave and, in most cases, hopeless. The correct treatment is surgical excision before the tumor is malignant. Roentgenotherapy is futile in both benign and malignant varieties of neurogenic tumors.

PERICARDIAL CYSTS

Ten pericardial cysts are included in the series.

Clinical Manifestations.—Discovery of the tumor in all of the cases resulted from routine roentgenologic examination. The cysts were asymptomatic.

Roentgenologic Examination.—Except for their anterior position, there is nothing characteristic about the roentgenographic appearance of pericardial cysts to differentiate them from other mediastinal cysts.

Location and Gross Appearance.—Pericardial cysts are thin-walled structures, usually in contact with the anterior chest wall and the parietal pericardium. Occasionally, they may be large enough to impinge on the lung or diaphragm. Anomalous development of the pericardium probably explains their formation.

Microscopic Appearance.—The walls of the cysts are made up of fibrous connective tissue lined by a layer of flattened endothelial or mesothelial cells. It is probable that, in the past, some of these cysts have been classified as cystic hydromas or cystic lymphangiomias.

Treatment.—Since surgical extirpation is the only means of establishing the benignity of a mediastinal tumor, operation should be recommended. None of the patients included in this report complained of symptoms referable to the cyst. There is only one case reported in the literature in which symptoms were attributed to a pericardial cyst. Pickhardt¹¹ describes a patient who complained of persistent thoracic pain which was relieved when a pericardial cyst of the anterior mediastinum was removed.

THYMOMAS

Six tumors of thymic origin have been studied. In four instances the lesion appeared to be benign. One patient with advanced myasthenia gravis was operated upon by Lieut. Colonel Meade, at the Kennedy General Hospital. A malignant thymic tumor was found, and could not be removed completely.

Clinical Symptoms.—Four of the six patients with thymic tumors had no symptoms referable to the mediastinal mass. The neoplasms were discovered on roentgenologic examination.

Case 2.—The patient, a young Negro, complained of nervousness and inability to work. A diagnosis of psychoneurosis, anxiety type, had been made overseas and the patient was returned to the United States. A mediastinal tumor was discovered on a roentgenogram made during examination for separation from military service. Unfortunately, the patient's complaints were minimized, and prostigmine tests were not made before the operation. It was not until the neoplasm was removed and the diagnosis of thymic tumor established that my failure to appreciate the possibility of myasthenia gravis in this patient became so painfully apparent (Plate II, D and E).

Roentgenologic Examination.—There are no definite criteria for the positive diagnosis of thymic tumors. Hampton¹² has made the important observation, however, that in many cases the tumor has a tendency to maintain the shape of thymus, as seen in roentgenograms of children. Another suggestive finding is that often the tumor is easily seen in the frontal projection but is not so apparent on lateral roentgenograms. The thymus is a flat, thin structure. Even when its dimensions are distorted by tumor formation, the shadow on the lateral projection is difficult to detect.

Location and Gross Appearance.—Thymic tumors are usually located in the anterior mediastinum in the substernal position; however, in one case in our series, the neoplasm was situated posteriorly. The gross appearance may vary considerably. Characteristically, the tissue is of reddish-gray color. The tumors originate in the neck, are commonly in the superior mediastinum, but may extend almost to the diaphragm.

Microscopic Appearance.—The microscopic appearance of thymic tumors varies greatly. In benign lesions the cells may be composed of somewhat disarranged but otherwise practically normal thymic tissue. Some malignant thymomas may have the appearance of a malignant lymphoma, while others of the reticulum cell variety are made up of endodermal thymic reticulum cells. Still other malignant varieties resemble epidermoid carcinoma or teratoid tumors, depending upon which element of the thymus predominates.

Treatment.—Treatment may be either surgical extirpation or radiation therapy, depending upon the type of thymic tumor. The rôle of radiation therapy in the treatment of thymic tumors will be considered in the discussion of therapeutic management of all mediastinal tumors. If the lesion does not respond to radiation therapy, surgical excision should be undertaken.

LIPOMAS OF THE MEDIASTINUM

Only four mediastinal lipomas have been removed. This is not surprising, since less than 40 cases have been recorded in medical literature.^{13, 14}

Symptoms.—Symptoms referable to lipomas of the mediastinum are those common to any mediastinal tumor, namely, pain, dyspnea or cough, depending upon the size and location of the mass. A long history of slowly progressing pressure symptoms may suggest a slowly enlarging fatty tumor.

Roentgenologic Examination.—There are no distinctive diagnostic features of the roentgenologic examination for lipoma of the mediastinum. Heuer and Andrus⁸ were able to predict the true nature of a mediastinal lipoma in two of their cases because the shadow of the mass on the roentgenograms became less opaque toward the periphery. This finding suggested to them that

MEDIASTINAL TUMORS

the tumor was composed of fat because it was more readily penetrable than the compact tissue of other tumors of the mediastinum.

Location and Gross Characteristics.—Lipomas of the mediastinum have been divided into three groups according to their location and form: (1) Tumors confined within the thoracic cage; (2) intrathoracic lipomas which extend upward into the neck; and (3) intrathoracic tumors with an extra-thoracic extension forming a dumb-bell configuration. In one case in this series there was extension into the neck.

Microscopic Appearance.—The microscopic appearance of a lipoma requires no comment.

Treatment.—Lipomas may grow to huge size. Watson and Urban¹⁴ have recorded the successful removal of a lipoma which weighed 6.8 pounds. The same authors mention a case in which an intrathoracic lipoma, weighing 17 pounds and 6 ounces, was discovered at postmortem examination.

MISCELLANEOUS TUMORS

Other varieties of mediastinal tumors found in army personnel include: One tumor classified as a fibroma (probably a neurofibroma); one thyroid adenoma; two tuberculomas of the mediastinum; one cyst arising from the esophagus; and an osteochondroma of the mediastinum. In three cases, enlarged inflammatory lymph nodes were discovered when the chest was opened to establish the nature of an intrathoracic mass. And in one instance biopsy of tissue of hilar mass revealed Boeck's sarcoid.

MALIGNANT TUMORS OF THE MEDIASTINUM

Fourteen malignant tumors of the mediastinum were found; including six malignant teratomas, two thymomas, one neurosarcoma, two lymphoblastomas and four Hodgkin's disease. With the exception of three cases, it was impossible to remove the tumor. It is surprising, and interesting, that in three cases tumors were removed, which proved, upon microscopic examination, to be Hodgkin's granuloma. In one case, operated upon by Major Paulson, at the Brooke General Hospital, the tumor had invaded the upper lobe and it was necessary to perform an upper lobe lobectomy, when the neoplasm was removed.

In two instances mediastinal tumors of unknown origin were extirpated. Microscopic examination of the tissue revealed Hodgkin's disease. One patient was operated upon by Colonel Grow, at the Fitzsimons General Hospital, the other at the Walter Reed General Hospital.

Case 3.—The patient, a 27-year-old white male, had had three years and three months of active military service. He was first admitted to a hospital for the treatment of frozen feet, after evacuation from the combat zone to England. At that time there was no history of chest pain, loss of weight or other indications of intrathoracic disease. The condition of his feet made it necessary for him to be moved to the Zone of Interior. While on furlough after returning to the United States, he lost weight and occasionally had low-grade fever with night sweats. A roentgenogram of the chest revealed a mass in the posterior mediastinum (Fig. 5). The possibility of Hodgkin's disease was not considered seriously.

The thorax was explored through a right posterolateral incision. A large mass was found in the posterior mediastinum. The mediastinal pleura was dissected from the mass and the mass removed by sharp and blunt dissection. The tumor had a lobulated appearance and was obviously of a malignant nature. There were many palpable lymph nodes near the pulmonary hilum (Plate III, A, B and C).

After excision of the mediastinal tumor, which proved to be Hodgkin's disease, radiation therapy was administered as soon as the incision of the chest wall had healed. During the following eight months, the patient gained 20 pounds. He has had no fever. There is no evidence of recurrence of the tumor on roentgenologic examination. He complains of some shortness of breath and occasionally notices a tight sensation in the chest.

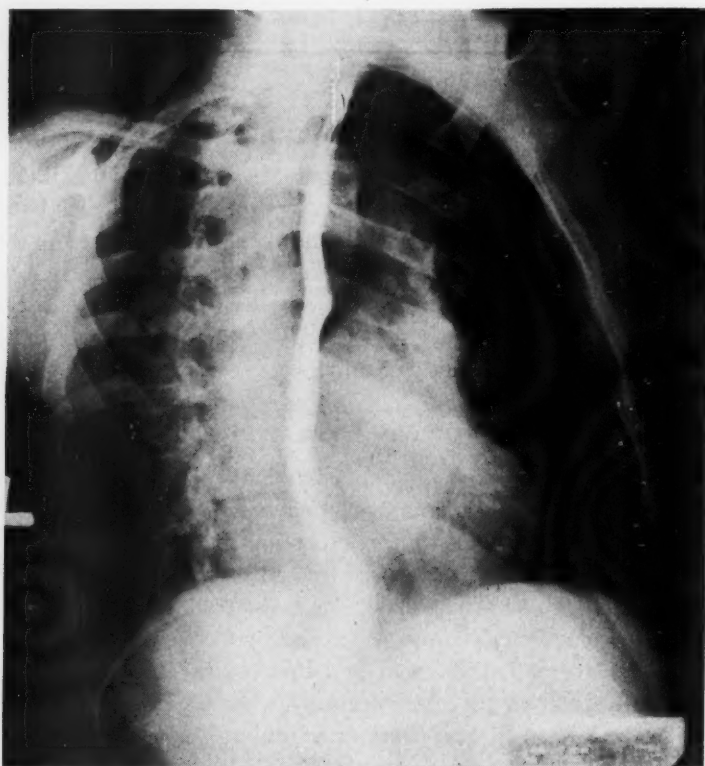
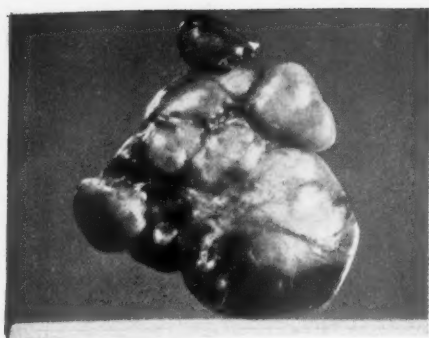


FIG. 5.—Roentgenogram of tumor which proved to be Hodgkin's disease.

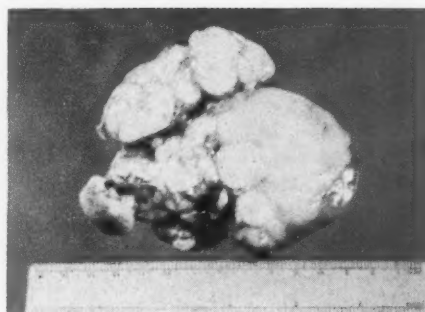
In the similar case operated upon by Colonel Grow, at the Fitzsimons General Hospital, radiation therapy was withheld, and it is planned to administer it when there is sign of recurrence. This patient has been under observation for a period of approximately nine months, with no evidence of recurrence of the tumor. It should be emphasized that surgical intervention would not have been recommended in any of these cases had the true nature of the lesion been established. It appears, however, that these patients have not been harmed, and probably have been benefited, by having the visible tumor removed. No

PLATE III.

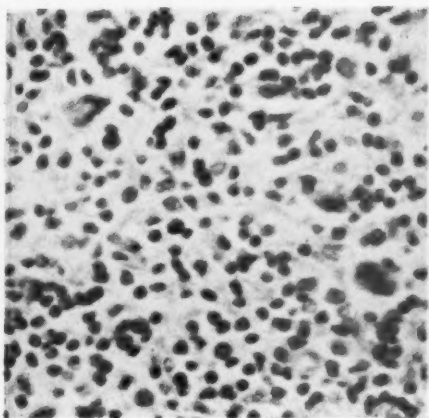
A



B



C



D



- (A) Photograph of tumor after removal.
- (B) Cut section of mediastinal Hodgkin's disease.
- (C) Microscopic appearance of tissue.
- (D) Photograph taken at the operating table of exposure of a neurofibroma of the mediastinum by the posterolateral approach.



MEDIASTINAL TUMORS

conclusions can be drawn concerning the results in any of the cases until they have been observed for a long period of time.

In the other cases of malignant neoplasms of the mediastinum, the tumor had invaded adjacent structures and the lesions were hopelessly inoperable. Tissue for microscopic study was obtained and the thorax closed.

RADIATION THERAPY AND SURGICAL TREATMENT OF MEDIASTINAL TUMORS

Unfortunately, there is no infallible method to determine preoperatively the exact nature of a mediastinal mass. Therapeutic endeavors are limited to radiation therapy and surgical removal. It is apparent, therefore, that the first decision which must be made is the choice between these two methods of treatment. For many years there has been a tendency to treat mediastinal tumors primarily by radiation therapy. If there was no effect upon the neoplasm, radiation therapy was abandoned and the possibility of surgical intervention considered.

Before refinements in operative and anesthetic technics made the exploration of the chest safe, this attitude was understandable. The accumulated reticence of physicians to recommend exploratory thoracotomy has probably resulted, however, in the injudicious use of radiation therapy in many cases.

Surgeons and radiologists experienced in thoracic disease should be able to predict in the majority of cases whether roentgentherapy will be successful. Even if errors in diagnosis occasionally result in thoracic exploration for tumors which will respond to radiation therapy, the danger to the patient from the operation is slight when compared to the deleterious effects of prolonged and ineffectual radiation therapy. Most benign tumors of the mediastinum and some malignant neoplasms are amenable to surgical removal. Radiation therapy will fail to reduce the size or to halt malignant degeneration of mediastinal tumors unless they are of lymphatic origin. Moreover, after prolonged exposure to roentgentherapy, the removal of the lesion will be more difficult and hazardous.

It is usually possible to make a tentative and reasonably accurate diagnosis of a mediastinal tumor of lymphatic origin. With few exceptions these are the only mediastinal tumors which will respond to radiation therapy. Neoplasms of lymphatic origin have a far greater tendency to produce clinical symptoms early and their roentgenographic appearance is fairly characteristic. If, after a test dose of roentgentherapy the neoplasm decreases in size, it can be assumed that it is of the lymphoma group and surgical intervention is not indicated. Properly employed, radiation therapy is invaluable, both as a therapeutic and diagnostic measure. Continued injudicious radiation, however, may be disastrous, and if after a fair trial the tumor is not affected, the method should be discontinued. Friedman,¹⁵ at the Walter Reed General Hospital, recommends an initial test dose of 750 r delivered to the center of the tumor. It should be emphasized, however, that about one-third of malignant lymphomas will require as much as 1500 r to affect the tumor. If, after a period of approximately one month, there is no change in the size of the tumor, thoracic exploration should be performed to determine the exact nature of the lesion.

EXPLORATORY THORACOTOMY

The choice between radiation therapy and surgical intervention will, of course, depend largely upon the risk of exploratory thoracotomy. It can be stated categorically that the danger of exploration of the mediastinum is trivial provided qualified anesthetists and surgeons are available and if the patient is in reasonably good general condition. If operation is delayed until signs and symptoms of pain, enlargement of the tumor, *etc.*, are apparent, the opportunity for successful extirpation of the lesion will usually have been lost.

The relative safety of a properly performed exploratory thoracotomy is demonstrated by our results, and the experiences of others. It is admitted that the majority of patients in our series are young men and are, therefore, good risks for major operations. In a total of 114 exploratory operations to determine the nature of a mediastinal mass (including five cases of aneurysms in which a correct preoperative diagnosis was not made), there were no deaths which could be attributed to the exploratory operation. There were no post-operative complications in patients upon whom an exploration and biopsy was performed. In three cases in which a tumor was removed, suppurative pleuritis developed. Adequate drainage of the empyema resulted in prompt healing. In one of these cases previously described, it was necessary to remove an infected right middle pulmonary lobe which had been eroded by a teratoma.

OPERATIVE TECHNIC

Ordinary fundamental principles of surgical technic apply to the extirpation of mediastinal tumors. Adequate exposure and precise, gentle handling of tissues is especially important.

One controversial detail in surgical technic is the route for effecting entry into the thorax. Some surgeons employ routinely the posterolateral approach to remove mediastinal tumors. Others prefer an anterior approach for tumors situated in the anterior mediastinum and reserve the posterolateral approach for lesions situated posteriorly. It is interesting that in the five Thoracic Surgery Centers in the Army there was never complete agreement concerning the preferable method for exposing a mediastinal tumor. Paulson, at the Brooke General Hospital, reflected his early training with Harrington by using a posterolateral approach for practically all mediastinal tumors. At the Fitzsimons, Kennedy and Walter Reed General Hospitals both the anterior and posterior incisions were employed, depending upon the location of the tumor. There is complete agreement, however, that if technical difficulties are anticipated, the anterior approach may provide inadequate exposure and a lateral or posterolateral incision is preferable (Plate III, D).

The surgical removal of benign mediastinal tumors is usually relatively easy. Huge benign tumors occasionally present difficulties. If the neoplasm has undergone malignant change, surgical removal is usually impossible. Even if a malignant tumor can be removed, the operation is often only a palliative measure.

Anesthesia.—Details of anesthetic technic and a discussion of the various

MEDIASTINAL TUMORS

anesthetic agents is not in the province of this report. Unhurried and safe surgery in the thorax requires expert anesthesia. The proper administration of intratracheal anesthesia makes the exploration of the chest and mediastinum as easy and as safe as exploration of the abdomen.

SUMMARY AND CONCLUSIONS

One hundred and fourteen explorations of the thorax have been performed at Army Thoracic Surgery Centers to establish the nature of mediastinal masses. In five cases the mediastinal tumors proved to be aneurysms. Biopsies of benign inflammatory lesions were obtained in five instances. Eighty-nine benign tumors of the mediastinum were removed successfully. In three of 15 cases of malignant tumors of the mediastinum, the mass was removed. In the remainder of malignant tumors, extirpation of the neoplasm was impossible. There were no deaths attributable to exploration of the thorax. All patients with benign tumors recovered promptly and returned to full activity.

Mediastinal tumors are relatively rare lesions, yet the routine roentgenologic examination of the chest has led to the detection of 94 of 109 cases of mediastinal tumors in this series. It is apparent that if this large number of neoplasms of the mediastinum were found in apparently healthy young men that the universal application of routine roentgenologic examination of the chest in individuals of all ages would result in the early diagnosis of many intrathoracic tumors. It should be emphasized again that if the diagnosis of a mediastinal tumor must wait until clinical manifestations are obvious, the chances of cure become remote.

REFERENCES

- ¹ Hare, H. A.: *The Pathology, Clinical History and Diagnosis of Affections of the Mediastinum other than those of the Heart and Aorta*, Philadelphia, P. Blakiston's Son & Co., 1899.
- ² Alford, J. E.: Congenital Bronchiogenic Cysts of the Mediastinum. *J. of Pediatrics*, **11**, 515-555, 1937.
- ³ Heuer, George J., and Andrus, William DeWitt: The Surgery of Mediastinal Tumors. *The American J. of Surg.*, **50**, 146-212, October, 1940.
- ⁴ Laipply, T. C.: Cysts and Cystic Tumors of the Mediastinum. *Arch. Pathology*, **19**, 153-161, March, 1945.
- ⁵ Brown, Robert K., and Robbins, Laurence L.: The Diagnosis and Treatment of Bronchiogenic Cysts of the Mediastinum and Lung. *J. Thoracic Surg.*, **13**, 84-105, April, 1944.
- ⁶ Womack, Nathan: Personal communication.
- ⁷ Harrington, S. W.: Intrathoracic Tumors. *Arch. Surg.*, **19**, 1687, 1929.
- ⁸ Harrington, S. W.: Surgical Treatment in 11 Cases of Intrathoracic Teratomas. *J. Thoracic Surg.*, **3**, 50, 1933.
- ⁹ Rusby, N. Lloyd: Dermoid Cysts and Teratomata of the Mediastinum. *J. Thoracic Surg.*, **13**, 169-222, June, 1944.
- ¹⁰ Kent, Edward M., Blades, Brian, Valle, Anibal Roberto and Graham, Evarts A.: Intrathoracic Neurogenic Tumors. *J. Thoracic Surg.*, **13**, 116-161, April, 1944.
- ¹¹ Pickhardt, O. C.: *ANNALS OF SURGERY*, **99**, 814, 1934.
- ¹² Hampton, Aubrey O.: Personal communication.

- ¹³ McCorkle, R. G., Hoerth, C. J., and Donaldson, Jr., J. M.: Intrathoracic Lipomas. *J. Thoracic Surg.*, 9, 568-582, 1940.
- ¹⁴ Watson, William L., and Urban, Jerome A.: Mediastinal Lipoma: A Case Report, *J. Thoracic Surg.*, 13, 16-29, February, 1944.
- ¹⁵ Friedman, Milton: Personal communication.

DISCUSSION.—DR. ALTON OCHSNER, New Orleans, La.: It is with considerable trepidation that a civilian discusses a paper dealing with Army experiences. It is heartening to see this material brought to the attention of the medical profession, because in the past these cases have not been treated correctly, largely because we did not know how they should be treated, and we instituted watchful waiting. As Doctor Blades pointed out, many patients developed malignancies, many developed infection, both conditions which greatly interfere with the removal of the tumor. If the mediastinal shadow is bilateral, it is more likely to be lymphoblastic. In the bilateral lesion, one is much more justified in employing roentgenotherapy before exploration. In unilateral shadows thoracic exploration, we feel, is justified early. We have treated four patients with unilateral mediastinal shadows in whom at operation a very small bronchiogenic carcinoma was found and, although the primary neoplasm was too small to be detected preoperatively, the involvement of the mediastinal nodes was massive and produced the mediastinal shadow.

I am happy that Doctor Blades has emphasized that any mass in the mediastinum which cannot be diagnosed definitely ought to be explored, because this is safer than procrastination.

DR. NATHAN A. WOMACK, St. Louis, Mo.: This presentation of Doctor Blades is very modest, and I think needs no comment. This huge series of intrathoracic tumors represents a most unusual experience, and the operative results speak for themselves. There is one point that I should like to make, having to do with the etiology of the so-called teratoma or dermoid of the mediastinum. Doctor Blades has referred to bronchiogenic cysts and bronchiogenic tumors of the mediastinum. I think his terminology is a good one. In times past, the explanation offered for these tumors has been most fantastic. It has been suggested that they have been caused by inclusions of skin into the anterior mediastinum during the formation of the anterior thoracic wall; that they represent misplaced blastomeres; that they were the result of misplaced sex cells. Such explanations are embryologically untenable. I think we have enough evidence now to show that these tumors, for the most part, represent the abnormal development of supernumerary lungs which takes place very early in embryonic life. I shall not offer our proof for this belief at this time, but will reserve that for later publication.

DR. PAUL B. MAGNUSON, Chicago, Ill.: It is quite appropriate that an orthopedic surgeon should discuss this paper, because he cannot be expected to know anything about the subject. However, Doctor Blades' paper was very instructive to me and was beautifully presented. He mentioned that 35 cases of a certain type of mediastinal tumor had been reported in the world literature up to this time, and then reports 23 additional cases operated upon by surgeons in the Army within a period of three years. These were diagnosed in a large percentage of cases, suspected in a small percentage, and produced in all cases at the operating table, with a minimal mortality.

When we consider that this has occurred in what was originally a select group of young men, how many cases have existed that have never been diagnosed nor reported? How many will be found in the millions of men discharged from the Army, to be cared for by the Veterans Administration? The possibilities of saving lives and preventing disability through proper examination radiologically, and otherwise, are perfectly enormous. If we can place these patients into the hands of doctors who know the possibilities, who know how to make an expert examination and who are furnished with the tools with which to work, undoubtedly in all branches of our various specialties there will be found cases which have been considered rare in the past; these will be brought to successful cure by a combination of personnel, equipment and placement, namely, medical schools, properly equipped and properly run hospitals located on the campus

MEDIASTINAL TUMORS

of our universities. This the Veterans Administration is planning to do. The whole problem is now up to the medical profession—to take care of fifteen million men over a period of the next 50 years. It is a tremendous undertaking. It offers a challenge to the medical profession which it is ready to accept and which, as a matter of fact, it has advocated. The Veterans Administration wants to give medical service of the highest type and asks your help in putting the plan into effect. God knows we need this help. This time we must not fail the veterans. The Veterans Administration is determined that the treatment of these men shall be in the hands of the best physicians in the country, and they, as represented by the Specialty Boards, the College of Surgeons, the College of Physicians, the American Medical Association and its component societies, have all given ample evidence so far that their desire is to be of service in this undertaking, not for a year or two, but permanently.

LT. COL. BRIAN BLADES, Washington, D. C.: Our ideas concerning roentgenotherapy are completely in accord with those expressed by Doctor Ochsner. I would not presume to prescribe the amount of this therapy to be employed as a test dose. It is important to remember, however, that pulmonary fibrosis caused by intensive radiation may make the cure worse than the disease. Friedman, at the Walter Reed Hospital, usually gives 750 R. delivered to the center of the tumor, in cases in which the tumor appears to be of lymphatic origin. About 25 per cent of cases of Hodgkins' disease will require as much as 1,500 R. to affect the neoplasm. If as much as 1,500 R. has been given, Friedman recommends waiting approximately one month and, after this period of observation, the chest should be explored if the tumor has not decreased in size.

ANGIOMATOUS MALFORMATIONS OF THE BRAIN*

SUCCESSFUL EXTIRPATION IN THREE CASES

COBB PILCHER, M.D.

NASHVILLE, TENN.

FROM THE DEPARTMENT OF SURGERY, VANDERBILT UNIVERSITY SCHOOL OF MEDICINE, NASHVILLE, TENNESSEE

IN 1928, Cushing and Bailey¹ wrote regarding the "venous angiomas" of the brain: "The surgical history of the reported cases shows not only the futility of an operative attack upon one of these angiomas but the extreme risk of serious cortical damage which it entails . . . the lesions, in short, when accidentally exposed by the surgeon, had better be left alone. . . ." Again, the same authors stated of the "aneurysmal angiomas": "To extirpate one of these aneurysmal angiomas in the active state would be unthinkable and so far as we are aware there is no report in the literature of the attempt having been made."

In the same year, Dandy², who preferred to call all of these lesions "arteriovenous aneurysms," wrote: "an aneurysm (*i.e.*, arteriovenous aneurysm) in the left hemisphere in a right-handed person is surely *noli me tangere* under all conditions . . . (in the right hemisphere) radical ligations or extirpations alone are curative, but are exceedingly dangerous to life and function and indicated in the minority of cases."

Among the 16 cases of Cushing and Bailey, and the eight cases of Dandy, no successful radical removal of the lesion was reported, nor was any such successful procedure discovered by these authors in their extensive reviews of the literature.

Since these two publications in 1928, many improvements in neurosurgical technic have been developed and a somewhat bolder attitude has sometimes appeared in the literature.

In 1933, Bailey³, in discussing the venous angiomas, stated: "In at least one case, radiation so reduced the vascularity that it was possible at a secondary operation successfully to extirpate the central lesion," but he does not state by whom or give other details of the case.

Mixter,⁴ in 1941, attempted the removal of a calcified angioma of the occipital lobe, but was forced to discontinue the procedure before the removal was complete. Ray⁵, also in 1941, reported exposure and decompression in four cases, but nevertheless stated: "Direct operative attack upon the lesions is dangerous, but might be indicated in selected cases."

In the same year, Northfield⁶ advised against any such radical procedure: ". . . the dangers of fatal hemorrhage and of extensive damage to the brain . . . forbid any attempt."

A single outstanding exception to this pessimistic attitude was the symposium on vascular tumors of the brain published by Bergstrand, Olivecrona and Tonnis.⁷ Few details of individual cases were given but Olivecrona had

*Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

successfully carried out the radical extirpation of cerebral vascular lesions associated with cutaneous naevi (Sturge-Weber's syndrome) in two cases and of "arteriovenous aneurysms" in three. Tonniss had removed one "angioma racemosum venosum."

Since the author believes that it is not only feasible but highly desirable to attempt radical extirpation of some of these formidable lesions, it seems wise to report three cases, in all of which such a procedure has been successful. These are the only instances in which true intracranial angiomas have been encountered. To be sure, large anomalous veins are sometimes seen on the cerebral cortex and have several times been ligated or coagulated in the hope of alleviating a convulsive state. The three lesions reported here, however, were not only vascular anomalies, but were *tumors*, in the space-occupying sense of the word. Their pathologic nature will be discussed later.

REPORTS OF CASES

Case 1.—G. S. (Vanderbilt University Hospital No. 102874): A 12-year-old Negro girl, was admitted from the Out-patient Department on November 6, 1939, because of convulsive seizures. Her first attack occurred at the age of 15 months. Thereafter, they came with steadily increasing frequency until at the time of admission, four or five or more seizures occurred each day. Many attacks were nocturnal, but there was no hour of predilection. She stated that she usually had a "peculiar feeling" immediately preceding the seizures, but could not describe this sensation. In the attacks, her head and eyes moved directly upward and tonic and clonic movements of the upper extremities occurred without predominance of either side. The lower extremities were seldom involved, but she had fallen on a few occasions. She seldom lost consciousness and could sometimes respond to questions during a seizure. Attacks usually lasted from a few seconds to two minutes. During the four years prior to admission, she had been incontinent of urine during nearly all attacks, but she had not injured herself. She stated that at times she had seen "animals" which she could not describe during attacks. She could not lateralize these visual phenomena.

There were no residual symptoms following attacks. Her development had been normal physically and she was in the seventh grade at school.

She had been born at full term following a normal delivery. There had been no injuries or significant illnesses. Her father had died of pulmonary tuberculosis one year prior to admission.

Physical Examination: The patient was a large, well-developed Negro girl, who was intelligent, alert and coöperative. Her memory and speech were normal. The head was well-formed. No bruit was audible. The optic disks were normal. The visual fields showed no defect. The neurologic and general physical examinations were completely negative. There were no cutaneous vascular lesions. Red, white and differential blood counts were normal. Urine and stool examinations were negative. The cerebrospinal fluid was under a pressure of 140 mm. of water and contained 2 cells per cu. mm. The total protein was 19 mg. per cent. The blood Kahn and the cerebrospinal fluid Wassermann were negative. The tuberculin test was strongly positive.

Roentgenograms showed an area of worm-like calcification occurring in thin double lines in the right occipital lobe immediately adjacent to the midline (Fig. 1).

The diagnosis was angiomatous malformation of the right occipital lobe. Because of the child's very frequent convulsions, radical removal of the lesion was advised.*

*Electro-encephalograms, had they been available when this child was seen, would have been of interest. However, there seemed little doubt of the causative relationship of the calcified lesion in the production of the convulsions, and this has been borne out by the postoperative course.

Operation.—November 9, 1939: Under intratracheal ether, an osteoplastic flap was reflected to expose the right occipital lobe. The following is quoted from the operative note: "The dura was then very carefully" opened close to the lateral sinus posteriorly and the dural flap turned back medially up to the sagittal sinus. The cerebral convolutions were flattened and the vessels on the surface of the brain extremely distended and somewhat tortuous. The outer aspect of the calcified area seen in the roentgenogram could at once be recognized by the greyish appearance of the pia along the vessels and the hard gritty consistency on palpation. Several veins which entered the sagittal sinus were carefully coagulated and divided. It was then possible to retract the occipital lobe laterally

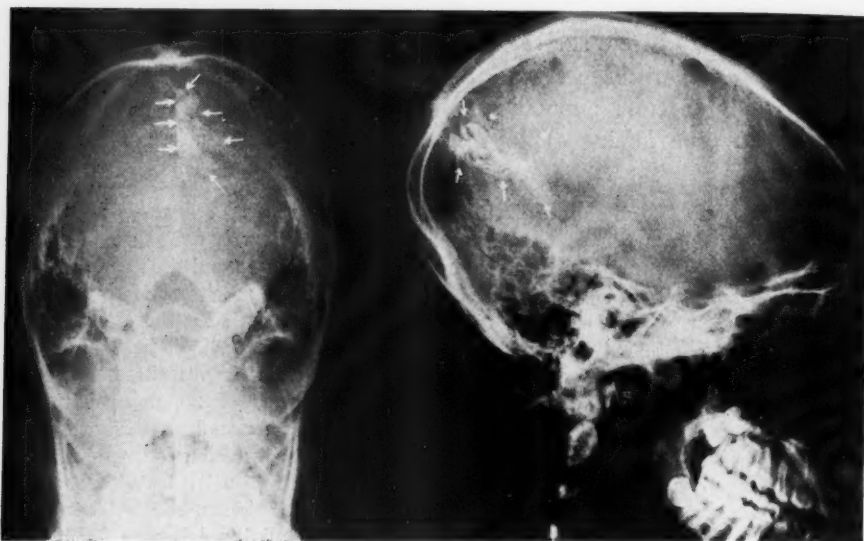


FIG. 1.—Case 1: The worm-like tangle of parallel lines of calcification lies on the medial surface of the occipital lobe.

and to follow down the calcified area along the medial surface of the hemisphere. This extended completely to the splenium of the corpus callosum. At this point, entering vessels were seen and it seemed likely that the calcification had occurred in the extremely vascular tissue around the mass of blood vessels which could be seen on the medial surface of the occipital lobe. There was no specific demarcation of the involved area and no reason to think that the lesion could be removed as a separate entity. I first removed a small cortical portion of it for microscopic study but this could be done only with great difficulty, the application of several silver clips and coagulation of numerous vessels. An attempt to go deeper into the hemisphere through this small cortical defect was met with profuse bleeding. I, therefore, was faced with the choice of backing out and leaving the child unimproved, or amputating the entire occipital lobe. Since the only defect to be attained from the latter procedure would be a left homonymous hemianopia, I decided to do this. The cortical vessels were coagulated along a line well anterior to the lesion and extending laterally to the temporal lobe. The incision was then made with the electric knife and was carried straight down the medial aspect of the hemisphere to the splenium of the corpus callosum. The occipital lobe was then completely resected, insofar as the posterior and medial aspects were concerned but no attempts were made to go far antero-laterally. When the lobe had been removed there was profuse bleeding in the depths of the cavity, but by means of suction and coagulation the large artery was found and con-

ANGIOMATOUS MALFORMATIONS OF THE BRAIN

trolled. I presume that this was the posterior cerebral artery. There was surprisingly little bleeding from elsewhere and this was easily controlled."

The usual closure was carried out in layers with fine interrupted silk. Blood loss had not been great and the patient's condition was satisfactory but she was given a transfusion at the end of the procedure.

Course.—The patient's recovery was prompt and uneventful. The presence of left homonymous hemianopia was evident as soon as she recovered consciousness and this was confirmed by perimetry on the 11th postoperative day. On that occasion and on numerous subsequent examinations, macular vision was found to be intact with no evidence of splitting. She was discharged on the 14th day, and returned regularly thereafter.

On all visits she was free of symptoms except for the hemianopia until March 5, 1940, four months after operation, when she was found to have a draining sinus in the line of incision and roentgenograms showed osteomyelitis of the bone flap (the wound had appeared to be completely healed on all previous visits). She was readmitted to the hospital and the bone flap removed, with complete healing after a period of drainage.

She has again been followed regularly until the present time, six years after operation. There has not been a single convulsion or other symptom of cortical irritation. The left homonymous hemianopia has persisted. Central vision has remained at 20/30 in each eye.

Pathology.—*Gross:* The excised occipital pole was discolored by subpial and subcortical hemorrhage on its medial aspect resulting from the biopsy and attempt at isolation of the lesion. The tortuous calcified vessels could be seen and felt to occupy a triangular area with its apex extending anteriorly and inferiorly on the medial surface of the lobe. The principal arterial supply certainly entered at this deep and anterior point and the venous drainage was largely through veins entering the longitudinal and lateral sinuses. No large vascular connections extended laterally.

When the lobe was sectioned, the gritty sensation resulting from calcification was felt to a depth of about 1 cm. from the medial surface. In the area of actual involvement by the lesion, the cerebral tissue was firm and rubbery, whereas the adjacent occipital tissue had a normal soft consistency.

Microscopically, the lesions in all three of the patients were quite similar and this aspect of their pathology will be discussed later in this paper.

COMMENT: The fact that the venous drainage of this lesion had to be occluded before its arterial supply could be exposed undoubtedly contributed to the difficulty of the procedure. Moreover, in retrospect, it was unwise even to attempt to isolate the lesion itself.

Since this patient was having four or five convulsive seizures daily, there can be no doubt that the complete postoperative freedom from attacks has justified the production of her homonymous hemianopia.

Case 2.—P. S. (Vanderbilt University Hospital No. 113219): A 12-year-old white girl, was referred by Dr. C. C. Howard of Glasgow, Kentucky, and admitted on March 27, 1941. She was right-handed. She had always been a healthy child. Sixteen months before admission, she had fallen from a bicycle, possibly striking her head, but not being rendered unconscious and having no residual symptoms. One year prior to admission, she had the first of a series of convulsions, while at school. Black spots appeared in front of her eyes, her right arm, hand and face felt peculiar, the fingers of the right hand began to twitch, the right arm jerked violently and this jerking spread to the right face and right lower extremity. She did not lose consciousness. The convulsive movements lasted two to three minutes. After the seizure she was drowsy and slightly confused, but could speak distinctly.

Similar attacks had occurred about every four weeks until admission, except for a period of three months during which no seizures took place. All attacks showed the same right-sided pattern, and never involved the left side. Consciousness was lost in two particularly severe convulsions. Speech was never known to have been disturbed. There were no residual symptoms following any attack, but for the three months prior to admission, the parents had thought the child to be somewhat apathetic, unable to concentrate as well as formerly and a little slow in cerebration. Nevertheless, she made good grades in school, played normally and did not complain of headache, visual disturbance or other neurologic symptom.

The breasts had begun to enlarge and pubic and axillary hair had appeared, but she had not begun to menstruate. She had been treated with some form of endocrine injections.

Physical Examination.—The patient was a thin, but intelligent, alert and cheerful girl, apparently just entering the menarc. The head was slightly asymmetrical due to a prominence in the left frontal area just above the hair line. This portion of the skull seemed a little protuberant but there was no localized mass and the area was not tender, red or fluctuant. No bruit was heard. The neck was not stiff and the general physical examination revealed no abnormality.

Memory was excellent and speech was normal. There was excellent enunciation, ability to read, to understand written and spoken speech and to write.

The optic disks, visual acuity and visual fields were normal. There was no abnormality of any other cranial nerve. Motor and sensory function were normal and equal on the two sides. No reflex abnormality could be demonstrated. Coördination, gait and station were normal.

Routine laboratory observations were normal throughout. Glucose tolerance curve was not abnormal. The cerebrospinal fluid pressure was 180 mm. of water. The fluid was clear and colorless and contained 6 cells per cu. mm. The total protein content was 55 mg. per cent. The Wassermann tests on blood and cerebrospinal fluid were negative.

Roentgenograms showed a thin skull, with normal sella turcica. In the left frontal area were two very thin incomplete circular lines of calcification, one quite large, relatively superficial and occupying at least one-third of the frontal area, the other smaller, deeper and medial to the larger. The appearance was that of calcification in the thin walls of two sacs (Fig. 2, above).

It was thought that the patient had some form of obscure cystic cerebral disease. All attempts to demonstrate any infections or parasitic systemic disorder failed. Operative removal of the lesion was advised.

Operation.—April 1, 1941: The following is quoted verbatim from the operative note: "Under ether anesthesia, a rather large left frontal flap was outlined and turned down. The skull was very thin and in some places actually had a rubbery flexibility. The prominence in the lower left frontal region, which had been visible and palpable from the outside, was due to an actual bulging of one of these thin and flexible areas of bone. When the bone flap had been turned down, the dura was also found to be very thin and very tense. A horseshoe incision was made in the dura with the base toward the midline. As the dural flap was reflected, it was found to be lightly adherent to the cortex in a number of places. These adhesions however were not vascular and were easily divided. When the dura was opened, a very remarkable appearance was presented. At the anteromedial border of the flap was a mass of enormous, tangled, tortuous vessels. The arachnoid about these was dense and opaque. Inferior to this mass was a fairly well-circumscribed bulging of the cortex about 5 cm. in diameter. This portion of the cortex was grayish-yellow in appearance and on palpation was very firm. There was obviously a hard underlying mass. After coagulation of the surface vessels, an incision was made in this area through the pia. This was fortunately done with the point of a knife rather than with the electrosurgical knife because the cortex turned out to be not more than 2 mm. in thickness, and beneath it there bulged a smooth reddish-purple mass which was fluctuant

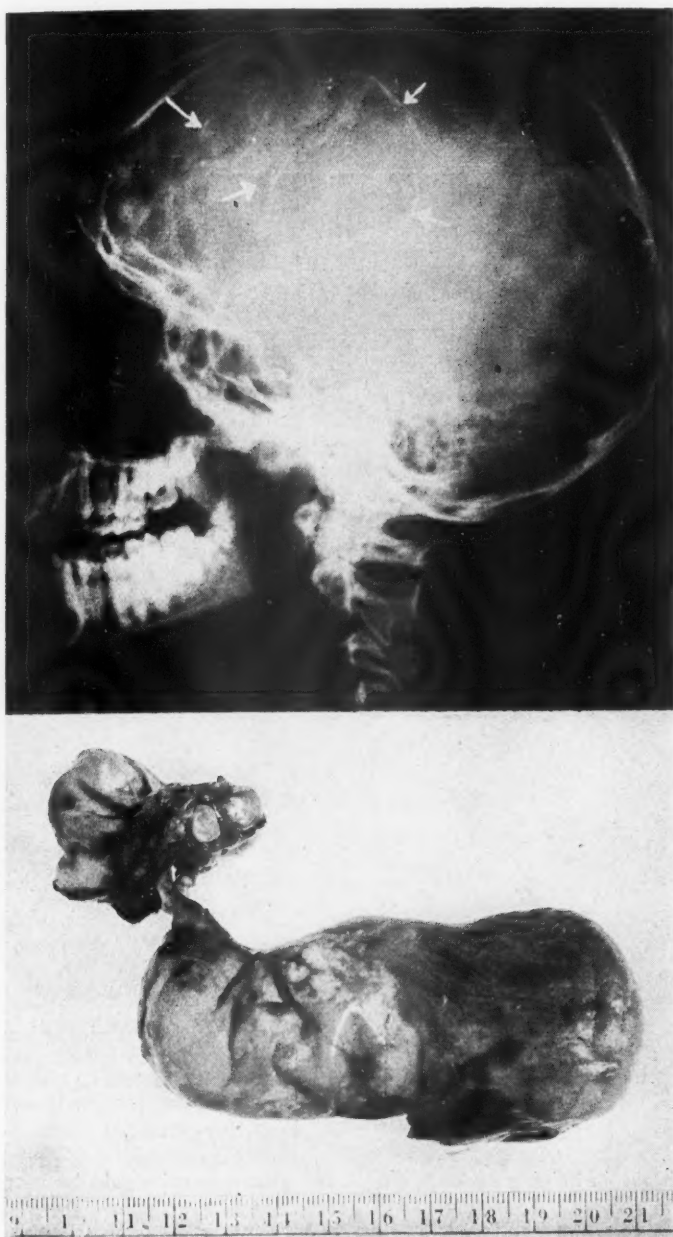


FIG. 2.—Case 2: Above: Roentgenogram showing the thin lines of calcification outlining the tremendous venous sacs. Below: Photograph of specimen removed at operation. The walls have collapsed and have been loosely filled with cotton.

and obviously represented a saccular aneurysm. It did not pulsate and was thought probably to be a venous sacculatation. I thought very seriously of simply closing the child's head and considering the case hopeless because of the tremendous danger of fatal hemorrhage that would exist if removal of the lesion were attempted. However, the mass was so

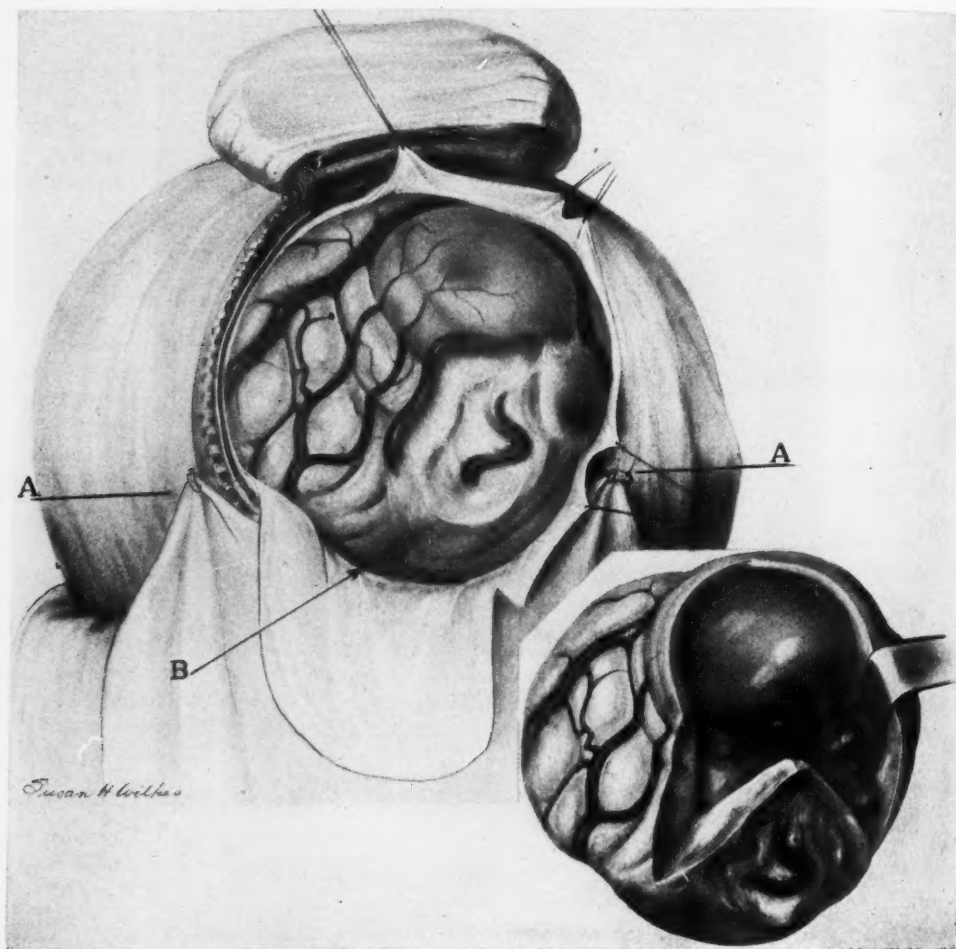


FIG. 3.—Case 2: Drawing made at operation. The two venous sacs appear above and to the right. The mass of arteries below is partly concealed by opaque, thickened pia-arachnoid. Line A-A represents the midline and point B the drainage of the principal vein into the displaced sagittal sinus. (The cortical vascular pattern is not accurate—see text.)

huge and the brain bulging so badly that I felt that removal would be necessary if the child were to survive. Accordingly, with great caution, dissection of the greatly bulging purple mass was begun. Only a few tiny vascular connections existed with the surrounding brain below, and it was ultimately freed completely except for its anteromedial aspect where it obviously communicated with the mass of vessels described above. The lesion was then attacked from above and medially. In order to do this, it was necessary to make two small incisions across the midline reflecting a small flap of scalp toward the right side. The bone was then rongeuired away completely across the longitudinal sinus. The latter was pushed far beyond the midline by the great lesion. I also had to remove

considerable additional bone anteriorly in an effort to gain control of the series of large arteries entering the mass from the middle cerebral distribution. When this had been completed and the dura opened actually to the sinus, it was seen that the large mass of veins culminated in a huge confluent channel which entered the sinus at only one point (Fig. 3). I could not be certain that other connections with the sinus did not come from the deeper portions of the longitudinal fissure, but I did not dare try to find out because it would have been fatal to obstruct the venous outflow before gaining control of the arterial inflow. Three large arteries entering the superficial vascular portion of the lesion from an inferior direction were controlled with silver clips and were divided between the clips. One of them broke loose but fortunately was easily controlled by coagulation and application of another clip. The pia was then divided in a semicircular line extending from the large mass anteriorly and medially along the border of the vascular superficial mass. When this line of incision was dissected more deeply, there appeared another globular mass lying beneath the tangled vessels. This was much smaller than the first one and evidently communicated directly with the latter. Gradually the dissection was carried deeper and deeper until the lesion was very nearly free except for its medial connection and except that I could not yet define accurately the connection between the large and small masses. At this location, gentle dissection was being carried out, when the lesion suddenly ruptured and there was an enormous flow of bright red blood. Quite obviously only a few seconds of this hemorrhage would have exsanguinated the child. Accordingly, a finger was inserted laterally and the entire mass which was already nearly free was turned on its central hinge. When this was done, the medial connections were torn and the entire lesion came away in one piece. The tremendous flow of blood gushed from two points—the one, the opening in the sinus which was seized between thumb and index finger and easily stopped; the other, a large artery, probably a branch of the anterior cerebral on the medial border of the hemisphere. Fortunately, I succeeded in grasping this with a bayonet forceps. Thus the hemorrhage was controlled within a few seconds of its beginning and the loss of blood, although alarming was controlled sufficiently quickly to avoid exsanguination of the child. Two silver clips were placed on the torn artery. The great vein entering the sinus was seen to have retained a small cortical connection and fortunately had not torn a hole in the wall of the sinus. It was, therefore, easy to apply silver clips with satisfactory control. There were several other small vessels which bled a little bit and which were easily controlled. When bleeding had ceased a transfusion was begun and the great yawning cavity inspected. At its bottom lay a smooth membrane which turned out to be the ependyma of the ventricle. By elevating the cortical margins, the choroid plexus could be seen posteriorly. The cavity was filled with saline and the dura closed tightly. Because of the removal of so much additional bone, the flap could not be held in place satisfactorily. I thought of securing it with wire or heavy silk thread but even then it would have fallen inward too much. It was removed from its periosteal attachment and set aside perhaps to be replaced later. Fortunately, it was possible to close the periosteum throughout almost the entire extent of the wound. The remainder of the closure was carried out as usual with interrupted silk throughout. A gutta percha wick was left in a small stab wound at the posterior border of the flap."

Course. Following operation, there were transitory motor aphasia and right hemiplegia, both of which were greatly improved on the second postoperative day. The wound healed promptly. At the time of her discharge on the 16th day, speech was normal and a slight right facial weakness was the only residual motor sign. The deep reflexes were still more active on the right than on the left, but the Babinski was negative and there was no clonus.

The child has been seen regularly until the present time (Fig. 4). For three months there were no symptoms, but, on July 6, 1941, she had a typical jacksonian seizure similar to the preoperative attacks. She was placed on anticonvulsant medication and since that time has had widely spaced minor attacks of "numbness" and sometimes

clonic twitching of the right hand and arm. Slight residual weakness of the right hand is present and, when excited, she sometimes has transitory difficulty in speaking.

Pathology. The large mass described in the operative note consisted of a single tremendously dilated vein. When empty and collapsed, it still measured 11 x 5 x 5 cm. (Fig. 2, below). Its lining was smooth and glistening and thin irregular plaques of calcification were grossly visible in its wall. It was connected by a relatively narrow neck whose lumen was 7 mm. in diameter and whose wall was much thicker than that of the distended sac, with the similar smaller sac which measured 5 x 3 x 2 cm. Attached to the neck and smaller sac was the mass of vessels which had collapsed to form an irregular small group of vascular channels with dense fibrous supporting tissue. It was at the point



FIG. 4.—Case 2: Photographs of patient (left, one month after operation; right, eight months after operation).

of connection between these vessels and the neck between the large venous sacs that the lesion had ruptured. For this reason careful dissection failed to demonstrate the exact pattern of the lesion. No other communication with the two sacs was demonstrable. Presumably, therefore, they represented enormous saccular dilatations of a huge vein. No definite gross arteriovenous communication could be found.

The microscopic findings will be discussed later.

COMMENT: In spite of its great size and potentialities for blood loss, this lesion represents technically the ideal type of angiomatous malformation for radical extirpation, for its arterial supply was superficial (including the unexpected branch of the anterior cerebral artery) and its draining veins converged into a single great channel. Preliminary cortical incision and dissection of the two great venous sacs undoubtedly made rapid removal possible when the moment of rupture came and greatly diminished the cerebral damage which would otherwise have been necessary.

The roentgenologic picture of calcification in this case is by no means typical of the angiomatic lesions and it is difficult to see how a correct diagnosis could have been made preoperatively.

Because of the enormous dilatation and extreme thinness of its walls, this lesion would certainly have ruptured spontaneously sooner or later. For that reason, its removal was a life-saving procedure. Nevertheless, the reappearance of convulsions is a disappointing and tragic sequel to the operation.

Case 3.—W. K. (Vanderbilt University Hospital No. 100748), a 29-year-old white farmer, was referred by Dr. Peery Sloan of Jamestown, Tennessee, and was admitted to the Neurosurgical Service January 29, 1943. However, he had first been seen in the Out-patient Department July 25, 1939. At that time he gave a four-year history of convulsive seizures occurring about every eight or nine weeks. There had been no preceding injury or significant injury. The attacks were said to begin with turning of the head to the right, but no other localizing features were recorded. The general physical and neurologic examinations were said to be negative and no abnormality was reported in roentgenograms of the skull. The glucose tolerance curve was normal. The diagnosis was idiopathic epilepsy and the patient was given phenobarbital.

He was not seen again for three years. During the interval, he had very few seizures, only two occurring in the year prior to his return. One month before his return, he had a sudden severe occipital pain which confined him to bed for a week after which it gradually subsided. A similar attack occurred four days prior to his admission to the Medical Service on August 17, 1942. On this occasion he became unconscious for two hours and was found by his local physician to have grossly bloody cerebrospinal fluid. He vomited several times.

On admission, he was drowsy, and complained of severe headache. His neck was stiff and the Kernig's sign was positive. No focal neurologic signs were observed on the Medical Service or by the neurosurgical consultant. The cerebrospinal fluid showed progressively less blood. The red cells and the xanthochromia gradually disappeared, as did the headache and stiffness of the neck. The diagnosis was spontaneous subarachnoid hemorrhage, probably due to aneurysm of the circle of Willis.

On September 5, 1942, pneumo-encephalograms were made and the wet films were interpreted at the time as negative. The ventricular system showed no deformity, displacement or dilatation. Unfortunately, the films were not examined by the neurosurgical consultant until four days later, when the patient had already been discharged from the hospital. This examination revealed faint but definite parallel lines of calcification in the left temporoparietal region with numerous irregular flecks of calcification immediately surrounding. The appearance suggested a mass of blood vessels.

The patient was sent for and finally returned to the Neurosurgical Clinic on October 10, 1942. There had been no symptoms in the interval. A slight right facial weakness and overactivity of the right patellar reflex were observed. He was advised to enter the hospital but did not do so until January 23, 1943.

In the interval, there had been transitory loss of consciousness on several occasions, but no recurrence of his violent headaches.

On admission, the findings were as before, and he also showed distinct weakness of the right upper and lower extremities, and a partial nominal aphasia. There was no dysarthria, disturbance of auditory or visual speech or of handwriting. He was right-handed. Tactile, painful, stereognostic and discriminatory sensations were normal. There was no papilledema. No bruit was audible over the head. Roentgenograms (Fig. 5) showed no change in the intracranial calcification.

Operative attack upon the lesion was advised, primarily because of the probability of recurrence of the spontaneous hemorrhage.

Operation.—February 1, 1943: The following is quoted from the operative note:

"Under intratracheal ether, a low left temporoparietal flap was turned down without difficulty. The dura was not particularly tense but there was a bulge extending from the medial end of the incision inferiorly through about the center of the exposed area. This was fluctuant and evidently overlay a very large vessel. Dura was opened widely as usual, disclosing that the bulge had indeed been caused by a huge vein running toward the midline. At its inferior end, it apparently communicated directly with a large artery evidently a continuation of the sylvian artery. The latter was quite tortuous and showed several small visible plaques of calcification. A number of other enlarged vessels, both arteries and veins, converged at the lower border of the flap. However, there were not sufficient vessels to account for the calcification seen in the roentgenogram and also it was recalled that the calcification was largely subcortical. Evidently these vessels were merely the surface connections of a much more extensive underlying angiomatous lesion. A distinct thrill was palpable over the lower portion of the visible tumor.

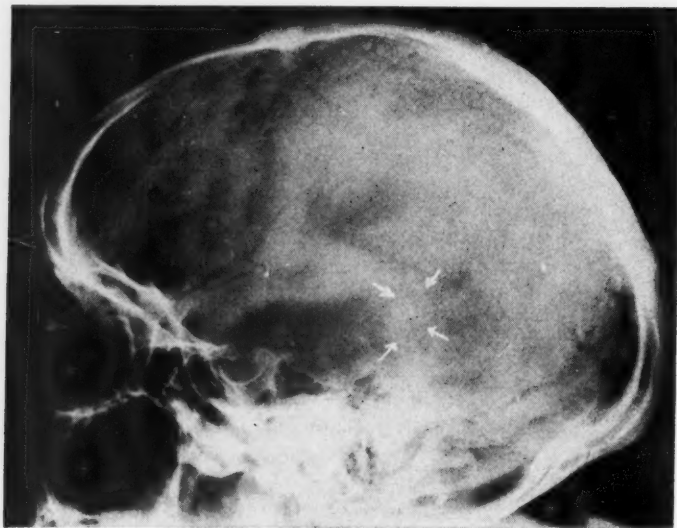


FIG. 5.—Case 3: Roentgenogram showing the faint pattern of lines of calcification indicating a vascular lesion. The calcified area represented only a small part of the total lesion, which weighed 26 Gm.

"I was very hesitant about undertaking the radical removal of this lesion since it seemed almost certain that I should get into serious hemorrhage. However, it was recalled the patient had had two spontaneous hemorrhages and, therefore, that he would almost certainly ultimately have a terminal rupture of the lesion. Therefore, it seemed that any risk was justifiable.

"I first set out attempting to control the entering blood supply. A silk stitch was placed around the large sylvian artery at the antero-inferior border of the flap. This was tied without difficulty and the thrill at once disappeared from the surface. The lesion was then gradually almost encircled by placing silver clips on all of the cortical vessels which led toward the lesion. The large vein leading up toward the midline was not occluded however since I feared that if this was done the lesion might rupture as the result of increased pressure. With the electric knife, an incision was begun on the anterior side of the lesion penetrating the cortex. Large subcortical vessels were encountered but were controlled at this point without difficulty. By blunt dissection this incision was carried down until an area of discolored brain tissue was reached which looked almost

ANGIOMATOUS MALFORMATIONS OF THE BRAIN

like a neoplasm. I suspect that this was a soft area into which hemorrhage had previously occurred. Inferior to this area a number of large tortuous tangled vessels came into view but I was not yet ready to tackle this deeper portion of the lesion since much of the superficial region still remained. I next tried to place a suture around the sylvian artery distal to the previous ligature. However, the needle evidently entered a deeper vessel and there was vigorous hemorrhage welling up beneath the pia. Something had to be done immediately and I, therefore, tried to coagulate the artery. This caused it to explode and there was violent hemorrhage for a moment. Further attempts at coagulation only made matters worse and the bleeding was finally controlled only by seizing a relatively large mass of tissue in two mosquito clamps. With great difficulty, suture ligatures were placed around these masses and tied down. Thus, the bleeding was finally controlled although I feared it might break out again at any moment.

"Next, the posterior margin of the lesion was attacked in much the same way. That is, the cortex was incised with the electric knife and this incision carried to a greater and greater depth by blunt dissection. The great medial vein had still not been touched. The inferior border was then encircled in the same way and when dissection had reached the depth of three or four centimeters it was apparent that the greater portion of the entering blood supply came from deep in the temporal region in addition to that obtained through the sylvian artery already divided. I proceeded as cautiously as possible to dissect out this entering blood supply from below, but while trying to do this, there was again a sudden violent hemorrhage due undoubtedly to tearing of some thin-walled vessel in the depths of the wound. Again with the greatest difficulty, the bleeding was controlled. During the course of this manipulation, the inferior connections of the angioma had been almost completely divided and its surface was relatively free. The hard calcified vessels could be easily palpated in addition to a number of large tangled vessels which were not calcified. The lesion was gradually dissected upward but once again another communicating vessel was torn and there was another severe hemorrhage. This was finally controlled by suture ligatures. The lesion was then gradually delivered out of the wound on the hinge of the huge vein extending medially. As this was done, another enormous deep vein appeared but it was secured without much difficulty and coagulated. A suture was then placed around the large medial vein and it was divided, thus, delivering the entire mass in a single piece. After much further difficulty, all bleeding from the clamped tissue below was secured by ligatures and by coagulation and silver clips. The wound was then quite dry. Patient had bled himself into a state of profound shock and was given two large transfusions and a plasma infusion. He rallied to some extent but still had a low pressure and was sweating profusely. Another transfusion was given after the end of the operation. The dura was closed, bone flap replaced and closure carried out in layers with interrupted silk."

Course.—As might have been expected following this frightening and extensive procedure, the postoperative course was rather stormy and recovery was slow. The temperature ranged as high as 103° F. for four days then gradually returned to normal. The patient had marked right hemiparesis and almost complete aphasia immediately after



FIG. 6.—Case 3: Photograph of patient 25 days after operation

The patient had marked right hemiparesis and almost complete aphasia immediately after

operation, but these functions also gradually improved. He was alternately drowsy and restless for two weeks, but was able to be out of bed on the 19th postoperative day and was discharged a week later. At this time, (Fig. 6) he understood everything said to him, could carry on simple conversation, but still was unable to name many common objects. He could not read or write. The right hemiparesis was present, but improving as was the right hemihypesthesia. There was astereognosis on the right and he had complete right homonymous hemianopia.

He has been seen regularly. Motor power returned steadily and he was able to return to work on the farm about three months after discharge. Speech functions improved greatly but the visual and sensory defects persisted. Nine months after operation he began to have fleeting "hot flashes" in the right face and upper extremity and these have persisted at varying intervals despite anticonvulsant medication. There have been no major seizures.

Pathology.—The specimen removed weighed 26 Gm. and measured 7 x 4 x 15 cm. It consisted almost entirely of a tangled mass of blood vessels, both arteries and veins, in the walls of which gritty areas of calcification were palpable. Small islands of brain tissue lay between some of the vessels and in one such area, the tissue was dark brown and firm, suggesting old hemorrhage. No definite arteriovenous communication could be demonstrated.

The microscopic pathology will be discussed in the following section.

THE PATHOLOGY OF THE ANGIOMATOUS MALFORMATIONS

Space does not permit a lengthy discussion of the mechanism of development of these lesions, a subject summarized by Bailey.³ Certainly they are congenital. Whether the number of vessels in such a malformation ever increases with the passage of time is controversial, but there can be no doubt that individual vessels in them increase in size by direct distension.

The great variability of the appearance and structure of the vessels of these lesions has led to a complicated and confusing terminology and to numerous attempts at classification. Cushing and Bailey,¹ and Dandy² have reviewed the early literature and more recent discussions have been published by Antoni⁸ and Ray,⁵ Cohen and Kay,⁹ Ronne,¹⁰ Northfield,⁶ and Bergstrand, Olivecrona and Tonnis.⁷ Cushing and Bailey divided the angiomatous malformations into venous and arterial groups. Dandy preferred to include them all under the term "arteriovenous aneurysm." While all must necessarily have a copious arterial supply and an extensive venous drainage, no direct arteriovenous communication is demonstrable in many cases. In none of the three cases herein reported was pulsation of the greatly distended veins visible or palpable. No studies of cardiac output or similar phases of the circulatory physiology have been published.

The vascular anomalies are most common in the distribution of the middle cerebral artery, but may occur anywhere in the cranial chamber. A large and unusual arteriovenous lesion of the base has just been reported by Alpers and Forster.¹¹

The occipital lobe angiomas such as that seen in Case 1 seem to have a definite and characteristic pattern which must represent a specific developmental defect, but no clear explanation is yet available. The majority of these occipital lesions have been associated with cutaneous vascular naevi in the

trigeminal area on the same side (Sturge-Weber's disease, Weber-Dimitri syndrome).^{9, 10}

The gross appearance of these malformations is extremely variable. Many appear to be composed almost exclusively of tangled, tortuous veins, while others present similar masses of arteries. Cases 1 and 3 represent perhaps the most common type of lesion. In this group, there is an indiscriminate mixture of arteries and veins, rarely with gross arteriovenous communications. Saccular dilatations of individual vessels such as were found in Case 2 are quite uncommon.

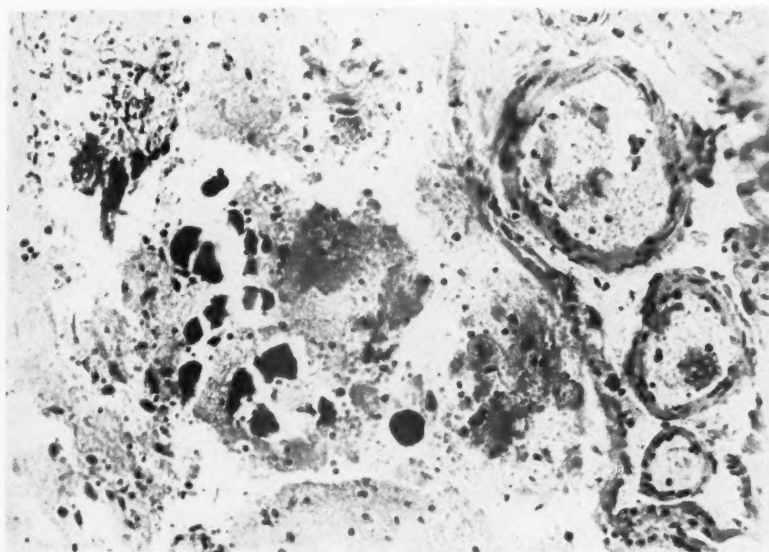


FIG. 7.—Case 2: Photomicrograph of vascular mass, showing area of calcification in the adjacent supporting tissue. (Hematoxylin-eosin. $\times 120$.)

The microscopic appearance of the vascular anomalies is characteristic and quite similar in nearly all cases. The abnormal collections of vessels lie in a matrix of partly degenerated brain tissue in which gliosis and fibrosis are prominent. Often no brain tissue is recognizable in the dense fibrous connective tissue (Figs. 7 and 8). Areas of hemorrhage and degeneration in various stages of organization may be encountered, if leakage has occurred, as in Case 3.

The vessels themselves vary greatly in their size and thickness and this variability appears in different portions of the same vessel as well as in different vessels. The wall of the great venous sac in Case 2 was composed of a thin, stretched fibrous membrane whose fibers were elongated and thin. No intimal or muscular layers could be seen in the sections. On the other hand, in this and the other lesions both arteries and veins of unusual and irregular thickness were seen.

Corresponding to the gross tortuosity there is a characteristic angulation

and infolding of the vessel walls themselves, sometimes resulting in an almost papillomatous appearance.

There is rarely any proliferation of the intima and the muscle is more likely to be thin or missing than thick. The dense elastic tissue, however, is often quite thick, its fibers extremely wavy and sometimes fragmented (Fig. 9).

Calcium may be deposited in the vessel walls but is also found in the supporting connective tissue adjacent to the vessels. In Case 1, almost the whole pattern of calcification seen in the roentgenograms was extravascular, but closely followed the vascular walls in its distribution.



FIG. 8.—Case 3: Photomicrograph showing the vascular pattern and the folded, irregular walls of the vessels. (Hematoxylin-eosin. $\times 46$.)

DIAGNOSIS

The clinical picture of the angiomatous malformations is variable and dependent upon the location, size and precise nature of the lesion. Nevertheless, the diagnosis can be made in the majority of cases.

Subjectively, convulsions occur in most cases. They may be generalized, as in Case 1, focal, as in Case 2, or equivocal, as in Case 3. The history is likely to be of long duration, and the patient frequently has been thought to have idiopathic epilepsy.

Symptoms of increased intracranial pressure may occur but are unusual. Localizing symptoms, such as paralysis, sensory impairment, aphasia and jacksonian seizures are dependent upon the location and size of the lesion, but no such symptoms may be present at all.

Objectively, the neurologic examination is variable and may be normal. The most common objective finding is intracranial calcification. In most cases,

ANGIOMATOUS MALFORMATIONS OF THE BRAIN

this calcification is in the form of characteristic vascular markings and is pathognomonic. In others, as in Case 2, it may be bizarre and misleading. The roentgenologic picture of the occipital lobe venous angiomas is recognizable at a glance.^{3, 9, 10}

An audible bruit has been heard in relatively few reported cases (and in none of these here reported). When present it is clear proof of a large arteriovenous communication.

The presence of other vascular anomalies and particularly of telangiectatic naevi in the trigeminal distribution is strong presumptive evidence that neurologic symptoms, if present, are also due to a vascular malformation.

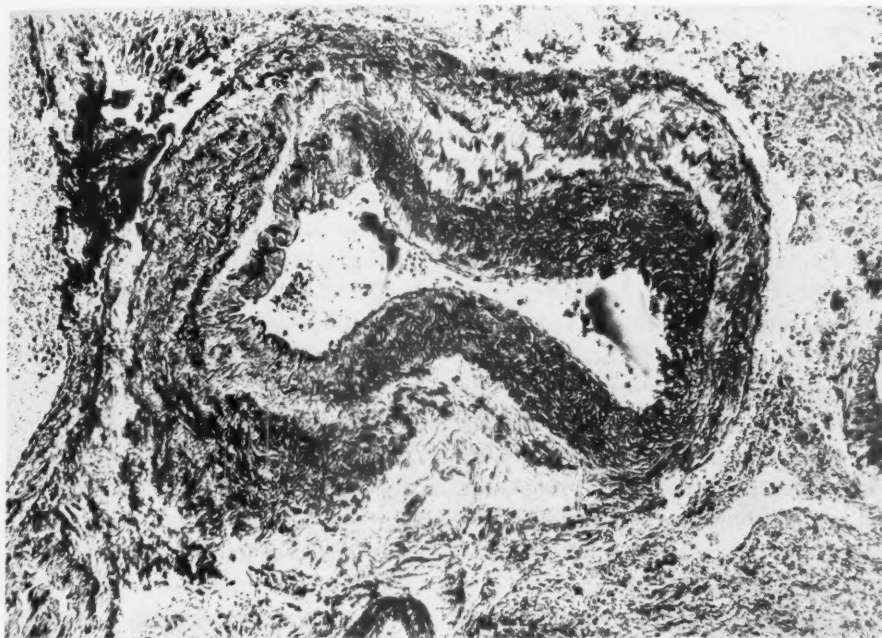


FIG. 9.—Case 3: Photomicrograph of a single artery in the lesion. The wall is angulated. The thick collagenous fibers of the adventitia are fragmented and corrugated. (Mallory's aniline blue-Orange-G. $\times 120$.)

Spontaneous rupture or leakage of intracranial vascular anomalies has occurred relatively infrequently, but nevertheless constitutes a constant threat. In Case 3, one and probably two, spontaneous hemorrhages had occurred and, in Case 2, the exceedingly thin walls of the great venous sacs made rupture and fatal hemorrhage an ever-present danger. Bailey³ records a case of fatal rupture of an angioma and a number of spontaneous hemorrhages from such lesions have been reported. Such a lesion must always be considered as the site of origin of any spontaneous subarachnoid, or subcortical hemorrhage.

In general, the existence of long-standing convulsions in the presence of intracranial calcification which shows a vascular pattern is the soundest basis for the diagnosis of angiomatous malformation, but the neurosurgeon must

be prepared to encounter such lesions in the absence of both of these manifestations.

CHOICE OF TREATMENT

To state that all angiomatous malformations of the brain should be radically removed would be foolhardy indeed. Many cause few and mild symptoms, others are bilateral, widespread and obviously inoperable, still others are completely inaccessible.¹¹ In these three groups, anticonvulsant medication (if convulsions occur) and deep roentgenotherapy should certainly be employed.

There is surprisingly little definite proof of the value of radiation in these cases. Most evidence is based upon clinical impressions and the author is not aware of any pathologic studies upon the subject.

On the other hand, there is considerable reason to believe, upon clinical evidence, that the angiomas which are preponderantly venous will regress in size and in clinical manifestations after radiation therapy. The author has seen two widespread intracranial vascular anomalies and at least three intraspinal lesions of similar type in whom marked improvement occurred (although in two of the latter group, the improvement was only temporary). The mechanism by which such improvement occurs is by no means clear.

Simple palliative subtemporal decompression may sometimes be indicated to preserve vision. It should be employed only when there is marked increase in intracranial pressure and sound reasons for not making a direct attack upon the lesion.

Ligation of the internal carotid artery has also been reported to result in improvement in some cases.^{2, 5} This, too, is a purely palliative measure and can only result in temporary diminution in the circulation through the lesion.

In the author's opinion, radical extirpation of a vascular malformation of the brain should be undertaken if the lesion is localized and is the cause of severe and progressive symptoms, such as frequent and uncontrollable convulsions, increasing neurologic deficits or spontaneous hemorrhage.

The three cases reported in this paper illustrate these indications quite well. All had single localized lesions. Case 1 had major convulsions which had occurred at the rate of four or five daily for eight years, and their continuance could surely be expected. Case 2 was operated upon without a definite preoperative diagnosis, but, once exposed, the lesion had to be attacked radically for two reasons: first, because of rapid expansion of the brain, and, secondly, because the thin-walled portion of the lesion was obviously on the verge of rupture. In Case 3, spontaneous hemorrhage, with imminent probability of recurrence, constituted a mandatory indication for radical therapy.

Despite the strong reasons advanced in these cases, the surgeon must decide upon the extirpation of one of these lesions only after profound consideration of all factors involved. Furthermore, he must occasionally have the courage and judgment to withdraw after actual exposure of the lesion.

TECHNIC OF RADICAL EXTIRPATION

To propound a uniform plan of attack for all of such a variable group of lesions is obviously impossible. The technical problems have been discussed at

some length in another publication.¹² In this paper, however, a few basic principles are worthy of consideration.

First of all, the surgeon must be aware of and prepared for the special difficulties likely to be encountered. A needle should be in a vein before the procedure is begun and large amounts of whole blood should be instantly available. Silver (or tantalum) clips, fibrin foam^{13, 14} or gelatin sponge^{15, 16} and thrombin or large amounts of muscle, an electrosurgical unit and a powerful suction apparatus are obvious necessities.

Preliminary ligation of the internal carotid artery has not been employed by the author, but should certainly be considered in some cases.

Once the lesion is exposed, its location, extent and vascular pattern will determine the plan of attack—or, indeed, whether it is to be attacked at all. If it is confined to an occipital or frontal pole, amputation of this portion of the brain is definitely indicated and may be a much simpler procedure than dissection of the lesion. In Case 1, dissection of the occipital lesion was attempted in hope of avoiding production of a visual field defect, but the attempt had to be abandoned and amputation of the lobe carried out. The initial attempt should probably not have been made at all.

Elsewhere in the brain, the surgeon's first attention should be directed toward identifying the principal arterial supply of the lesion and determining whether it can be controlled. If such control is not considered feasible, the operation should, if possible, be abandoned, for uncontrollable hemorrhage is almost a certainty.

If the arterial supply can be isolated, it should be the first object of attack. Under no circumstances should the principal draining veins be occluded until the entering blood supply has been shut off. It must always be remembered that one or more large arteries on the surface may furnish only a portion of the arterial supply. Thus, in Case 2, the supply came from both the middle cerebral and anterior cerebral distributions and, in Case 3, rupture of unexpected deep temporal arteries nearly resulted in fatal bleeding.

Dissection of the lesion itself should begin away from its major venous drainage and, in a sense, the latter should be used as a hinge or pedicle upon which the lesion is gradually delivered. Fortunately, most of the great veins will drain toward the surface and their ultimate control is not usually exceptionally difficult.

Considerable hemorrhage is inevitable even under favorable conditions. It is, therefore, upon the surgeon's ability to proceed rapidly yet with due concern for the control of vessels as they are encountered and for the integrity of the adjacent brain tissue that the patient's life will depend.

RESULTS OF RADICAL OPERATION

Cases are too few for any statistical conclusions regarding the safety of extirpation of the angiomatous malformations. Although all three of the cases here reported recovered, a formidable mortality rate must be anticipated in any large series of cases. As already pointed out, however, a large risk may well be justifiable in such cases as these.

From the point of view of end-results, the outcome cannot often be expected to be perfect regardless of the success of the technical procedure. In Case 1, the patient has been completely relieved of convulsions for six years, but she has a permanent homonymous hemianopia. Case 2 has had a recurrence of convulsions but is free of the imminent risk of fatal rupture of the lesion. Similarly, Case 3 has recurrent fleeting paresthetic attacks but will certainly have no more spontaneous hemorrhages, and is seemingly relieved of major convulsive seizures.

SUMMARY

Three cases in which large angiomatous malformations of the brain were radically removed have been described.

The pathology and diagnosis of such lesions, the indications for their removal and the technic of their radical extirpation have been discussed.

REFERENCES

- ¹ Cushing, H., and Bailey, P.: Tumors Arising from the Blood Vessels of the Brain. Chas. C. Thomas, Springfield, Ill., 1928.
- ² Dandy, W. E.: Arteriovenous Aneurysm of the Brain. *Arch. Surg.*, **17**, 190, 1928.
- ³ Bailey, P.: Intracranial Tumors. Chas. C. Thomas, Springfield, Ill., 1933.
- ⁴ Mixer, W. J.: Case Records, Massachusetts General Hospital: Case No. 27201. *New Eng. Jour. Med.*, **224**, 863, 1941.
- ⁵ Ray, B. S.: Cerebral Arteriovenous Aneurysm. *Surg., Gynec. and Obst.*, **73**, 615, 1941.
- ⁶ Northfield, D. W. C.: Angiomatous Malformations of the Brain. *Guy's Hosp. Rep.*, **90**, 149, 1940-41.
- ⁷ Bergstrand, H., Olivecrona, H., and Tonnis, W.: Gefassmissbildungen und Gefassgeschwulste des Gehirns. Thieme, Leipzig, 1936.
- ⁸ Antoni, N.: Vier Falle seltenerer Gefassgeschwulste des Zentral nervensystems. *Acta Chir. Scand.*, **85**, 7, 1941.
- ⁹ Cohen, H. J., and Kay, M. N.: Associated Facial Hemangioma and Intracranial Lesion (Weber-Dimitri Disease). *Am. Jour. Dis. Child.*, **62**, 607, 1941.
- ¹⁰ Ronne, H.: A Case of Sturge-Weber's Disease. *Acta Derm.-Venerol.*, **18**, 591, 1937.
- ¹¹ Alpers, B. J., and Forster, F. M.: Arteriovenous Aneurysm of Great Cerebral Vein and Arteries of Circle of Willis. *Arch. Neurol. and Psychiat.*, **54**, 181, 1945.
- ¹² Pilcher, C., in Brancroft, F. W. and Pilcher, C.: *Surgical Treatment. The Nervous System*, Chap. 13. Lippincott Co., Philadelphia, 1946.
- ¹³ Ingraham, F. D., and Bailey, O. T.: The Use of Products Prepared from Human Fibrinogen and Human Thrombin in Neurosurgery: Fibrin Foams as Hemostatic Agents: Fibrin Films in Repair of Dural Defects and in Prevention of Meningocerebral Adhesions. *Jour. Neurosurg.*, **1**, 23, 1944.
- ¹⁴ Ingraham, F. D., and Bailey, O. T.: Clinical Use of Products of Human Plasma Fractionation. III. The Use of Products of Fibrinogen and Thrombin in Surgery. *Jour. Am. Med. Assn.*, **126**, 680, 1944.
- ¹⁵ Light, R. U., and Prentice, H. R.: Surgical Investigation of a New Absorbable Sponge Derived from Gelatin for Use in Hemostasis. *Jour. Neurosurg.*, **2**, 435, 1945.
- ¹⁶ Pilcher, C., and Meacham, W. F.: Absorbable Gelatin Sponge and Thrombin for Hemostasis in Neurosurgery. *Surg., Gynec. and Obst.*, **81**, 365, 1945.

AN ANALYSIS OF BRAIN ABSCESES OBSERVED DURING THE PAST THIRTY YEARS*

ERNEST SACHS, M.D.

ST. LOUIS, MO.

AFTER reading the paper by Pennybacker, published last June in the Proceedings of the Royal Society of Medicine, in which he analyzed a series of 50 cases of brain abscess observed during the past 6.5 years, and because of the very important contribution to this subject made by Clovis Vincent, in 1936, I decided to review our entire experience.

In the past 30 years, 142 cases of brain abscess have been seen in our clinic. In 128 of these 142 patients, the abscess was found at operation, leaving 14 who were operated upon in whom the abscess was not located; of these 14, all except two were seen before the discovery of ventriculography.

Partly because I have followed the principle of operating upon every patient with a brain abscess, regardless of how grave his condition was, our over-all mortality is higher than in other clinics. For example, ten of the 128 patients in this series were unconscious when operated upon, and died within 24 hours. There were others who were in an equally serious condition, but I have arbitrarily called only those patients moribund who died within 24 hours. We have felt justified, however, in operating upon these desperate cases because we have had a few who have recovered, though they seemed moribund.

From time to time, a small series of cases has been reported with astonishing results. All of these cases were encapsulated abscesses. The outstanding series is that of Macewen, who reported 19 cases operated upon with 18 cures; but in that very table, there were six other patients who were not operated upon but who died.

In 1923, Dowman reported a series of encapsulated abscesses which had been drained with excellent results, and, in 1930, Coleman reported 26 such cases with four deaths. In this paper, Coleman said: "It is well known that septic encephalitis with formation of small abscess regardless of treatment is practically always fatal." In 1924, and again in 1936, King reported his method of treating such cases, which is known as marsupialization.

In 1935, King made a very important contribution; he described a method of sucking out septic brain material, and said, "This procedure may one day be utilized in certain suitable cases of suppurative encephalitis or phlegmon of the brain in which there is but little tendency to encapsulate." A year later, Vincent reported seven cases treated in this way, with six cures.

There are many cases of brain abscess which do not belong to what is generally conceded to be the favorable type—the encapsulated abscesses—and these unfavorable ones are the ones we must learn to treat more effectively. In fact,

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

the prime purpose of this review is to consider the care of those cases hitherto thought almost hopeless.

In analyzing our series, I have excluded only one group—the abscesses secondary to pulmonary infection. Both Pennybacker and we have had uniformly bad results in this group. The mortality has been almost 100 per cent. Pennybacker lost 11 out of 12 patients, and we lost 19 out of 20. These bad results are due, I believe, first, to the prolonged and debilitating illness these patients have had; and second, and even more important, to the type of organism which is responsible—an anaerobe which is not found in other brain abscesses. Patients with this type of organism have had huge abscesses before they showed any symptoms. The first warning of any intracranial involvement has usually been a convulsion followed by unconsciousness or coma. Very few of our patients presented any signs of pressure, and only three had choked disk.

Excluding this group, we have 108 cases to consider, and I have not attempted to classify them either according to etiology or location, because I believe that the outcome depends primarily upon the treatment. As stated above, we have operated upon all cases of brain abscess, no matter how grave their condition.

TABLE I
BRAIN ABSCESS—128 CASES

Cerebral, 97 (moribund, 9)	Drained	40	11 cured
	Aspirated	38	15 cured
	Marsupialized	11	9 cured
	Marsupialized and excised	2	2 cured
	Excised	6	6 cured
Cerebellar, 11 (moribund, 1)	Aspirated	9	5 cured
	Drained	2	0 cured
Abscesses secondary to lung suppuration		20	1 cured

In our clinic, aspiration of cerebral abscesses has been somewhat more successful than drainage, but the mortality with both methods has been high. In reviewing the 52 deaths in this series, it is now clear that we used to aspirate cases repeatedly, even after a capsule was well formed, and drained others in whom a capsule had not yet formed. In the last few years, I have become more and more convinced of two things; one is that aspiration should be used only until a capsule has formed, and that the abscess should then be excised, and the other is that the only time drainage should be used is when the abscess has ruptured in the course of excision and, therefore, has to be marsupialized. This is the policy which we have been following during the last three years. Of 18 cases in that period, 11 recovered. All were marsupialized or excised. Of the seven who died, one was moribund, one had been home for more than six months and was apparently well when she suddenly died, presumably from another abscess. Three had meningitis in addition to an abscess at the time of admission, and the seventh case was aspirated three times in the hope that a capsule would form. In this last instance, the abscess should have been sucked out at the time of the first aspiration.

In patients with cerebellar abscesses, the only ones who recovered were

those in whom the abscess had been aspirated. We have never attempted to excise a cerebellar abscess, and I have found no record, either in Pennybacker's or Vincent's reports, where this was done.

Whenever possible, it is desirable to postpone excising an abscess until it has become encapsulated, and undoubtedly penicillin has helped materially in tiding patients over the acute stage and giving the infection time to become walled-off. Furlow has recently reported six cases from the Naval Hospital in San Diego in whom, with the use of penicillin, the infection became localized and encapsulated.

In 1927, I first treated two patients by marsupialization, and, in 1929, treated a third by excision of the abscess. All three of these patients recovered, but I did not realize at that time that this was the method which we must attempt to employ in all cases of cerebral abscess.

In order to get patients in condition for this procedure, they must be treated with penicillin while in the acute stage, aspirated, sometimes several times, and, thus, tided over, if possible, until the abscess is ready to be excised. Vincent advocates what he calls a decompression during this period of waiting. By that he means removing the bone over the region of the abscess but not opening the dura. We have not done this. I have never felt that removing bone had any decompressing effect. Pennybacker had made use of this procedure occasionally, but feels that, as a rule, repeated aspiration will tide the patient over until a capsule forms. I do not feel as optimistic about this as Pennybacker, because we had ten cases in our series who died within 24 hours after the first aspiration so that there was no chance for a capsule to form, and I doubt whether penicillin therapy could have changed the outcome. However, that is certainly the procedure to follow, namely, to give large doses of penicillin to patients with acute abscesses, aspirate them in order to tide the patient over the acute stage, then excise the abscess completely and remove by suction all brain tissue that shows any sign of encephalitis.

In the 19 cases in our series which were marsupialized or excised, five had acute abscesses, and these were sucked out and treated, as suggested by King and Vincent. In some of the marsupialized cases, much of the capsule was excised, but as it was impossible to remove all of it, these cases were drained. The six excised cases were sewed up tightly, and had primary unions.

CONCLUSIONS

- To sum up, we have reached the following conclusions:
1. No unencapsulated abscess should be drained.
 2. During the acute stage, penicillin is an invaluable aid in bringing about encapsulation.
 3. Aspiration, except in cerebellar cases, should be used only as a palliative procedure until more radical treatment can be instituted.
 4. Excision without drainage is the ideal procedure, but frequently marsupialization must be resorted to if, in the course of an excision, the abscess has been ruptured.

REFERENCES

- Coleman, C. C.: Some Observations on the Drainage of Subcortical Brain Abscess. Archives of Surgery, **10**, 212-216, January, 1925.
- Dowman, C. E.: The Treatment of Brain Abscess. Archives of Surgery, **6**, 747-754, March, 1923.
- Furlow, L. T.: Penicillin as an Adjunct to Surgery in the Treatment of Brain Abscess: A Report of Six Cases. Southern Medical Journal (Journal of the Southern Medical Association). **38**, No. 5, 312-320, May, 1945.
- King, J. J.: Treatment of Brain Abscess by Unroofing. Surg. Gynec. & Obst., **39**, 554-568, November, 1924.
- Idem.*: Brain Abscess. ANNALS OF SURGERY, **103**, 647-668, May, 1936.
- Pennybacker, J.: Discussion and Treatment of Cerebral Abscess. Proceedings of the Royal Society of Medicine. **38**, 431-440, 1945.
- Vincent, C., et al.: Sur Une Méthode de Traitement des Abscès Subaigus et Chroniques. Masson & Cie, Paris.

CRANIOTOMY AND TOTAL DISSECTION AS A METHOD IN THE TREATMENT OF ABSCESS OF THE BRAIN*

EDGAR F. FINCHER, M.D.

ATLANTA, GA.

FROM THE DEPARTMENT OF SURGERY, EMORY UNIVERSITY SCHOOL OF MEDICINE, EMORY UNIVERSITY AND ATLANTA, GA.

THERE are no recorded experiences in the literature where a purposely planned surgical attack has been made to completely resect every gross vestige of a demarcated abscess located within the brain tissues. The idea of total extirpation of such an abscess is not a new concept. Such reports refer only to those experiences in which the abscess has been removed *in toto*.^{1, 2, 3} The recoveries in these cases have been ideal. Where a rupture occurred,⁴ or there was wound contamination, the serious complications, sequelae or protracted hospitalization, as have happened with all other of the numerous surgical methods in treating brain abscesses, have followed. The few experiences to be cited here suggest that when intact removal is impossible that complete dissection with the patient fortified⁵⁻⁸ against an infectious-spread may be a better method than incision and drainage, simple aspiration or marsupialization efforts. It is physically obvious that dissection efforts in a "diffuse infective encephalitis" or "a pus-containing cavity with ragged wall consisting of softened brain tissue" (Sargent¹) would not be considered as suitable cases. For these, systemic treatment and the recent experiences of Furlow,⁸ using penicillin, offers an optimistic hope that in the future better results may be accomplished in these cases than has been accomplished in the past. The author, as has almost every other neurologic surgeon, has had the rare experience of removing a "brain tumor" *in toto*, to learn later that the central cavity of the very thick-walled granuloma contained bacterially active pus. Again, the treatment of these, although fundamentally it does not differ, is not within the scope of this communication and is purposely omitted. Before the introduction of the sulfa derivatives and penicillin, the opening of a pus-containing lesion at the time of a craniotomy immediately brought forth the fears of a meningitis, prompted immediate drainage and, if a postoperative fatality was escaped, it usually meant a subsequent sacrifice of the osteoplastic flap, rather likely a cerebral fungus formation, and a prolonged hospitalization necessitating daily care and constant attention. Although the first case in this series was prompted somewhat by virtue of a necessity, the other four have reacted so favorably it is proposed to add subsequent cases in order that an accurate evaluation and comparison with other methods of treatment may be accomplished.

CASE REPORTS AND COMMENTS

Case 1.—A boy, age 4, was taken ill with bilateral earache on December 10, 1941. Three days later the left drum was incised and sulfathiazole by mouth begun. There was no aural drainage. On December 17, he developed pneumonia, and the left ear began to

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

drain pus. The pneumonia rapidly cleared. On December 20, a diagnosis of mastoiditis was made; this diagnosis was confirmed at operation two days later. He was discharged from the hospital on December 30, apparently well.

February 7, 1942: His mastoid wound had healed and he had no complaints. The following day he complained of headache and the day after this he had an associated forceful vomiting accompanying the progressive headaches. On February 10, a motor aphasia developed, and within 24 hours a complete right hemiplegia was present. On February 12, a left temporal abscess was aspirated; three days later tube drainage was instituted.



FIG. 1.—Showing the previous trephine skull defect through which the thorium dioxide was injected into the abscess cavity. This media only permitted visualization of the most superficial cavity.

The neurologic symptoms rapidly disappeared and by April 1 the wound had healed and the child again was discharged from the hospital. Ten days later all the neurologic symptoms recurred and, again, on April 17, tube drainage was instituted, but this time the aphasia, hemiplegia and projectile vomiting failed to clear. The attending neurosurgeon was called to military duty and the child was referred for further neurosurgical evaluation. With each reappearance of symptoms or temperature elevation this child was given sulfathiazole.

Physical Examination.—April 27, 1942: The patient was a lethargic, emaciated, acutely ill, unresponsive child. There was a bulging defect in the posterior temporal area on the left, with an encrusted scab in the center of a 1.5-inch surgical scar. This elevation was soft to palpation but exhibited no free pulsations. There was a bilateral choking of both optic nerves. Right hemiparesis was demonstrable. No conversation could be elicited from the child.

ABSCESS OF BRAIN

Aspiration and Thorium Injection.—April 29, 1942: The old left temporal scalp scar was excised. An abscess was entered with a ventricular needle less than 1 cm. from the dural level; approximately 60 cc. of pus was aspirated and 10 cc. of thorium dioxide was injected into the abscess cavity. Culture of the pus resulted in a growth of influenza bacilli.

Treatment and Progress.—Sulfadiazine by mouth was administered daily, and a blood level of 9.8 mg. was maintained. Three days after aspiration drainage, speech had returned and the right hemiparesis was disappearing. On May 5, the spinal fluid pressure was over 300 mm. of water and the fluid contained 27 cells per cubic centimeter. The thorotrast shadow, which, on April 29, was visualized as a cortical shadow in the middle portion of the temporal lobe, had shifted, by May 4, to a more posterior position and nearer to the midline (Fig. 1). The bulging scalp became more tense and the herniation increased the scalp elevation.

Craniotomy-Dissection of Multilobular Abscess.—May 9, 1942: The former wound was transformed into an enlarged hockey-stick scalp incision. The original trephine opening was enlarged with the bone rongeurs to a diameter of 5 cm., exposing the posterior midparietal, the anterior midoccipital and the superior posterior temporal lobes. The gangrenous edematous cerebral fungus was sacrificed with the cautery. The abscess stalk was a part of the cerebral fungus, so that an abscess cavity was immediately entered. This abscess cavity harbored an ounce of pus, and when this had been thoroughly and repeatedly irrigated and its location thoroughly established, this cavity did not correspond to the thorotrast outline on the roentgenogram of May 4. A small dural flap was then turned down and an exploratory needle introduced in a new area superior to the exposed cavity. At a 2.5-cm. depth a new resistance was encountered. The initial abscess capsule was then dissected from out of the white matter and in its superior as well as posterior limits a dumb-bell effect was encountered. Each of these continuities with the surfaced capsule broke into separate abscess cavities, each being as large as the first. As the pus was removed by suction, dissection of the respective capsules was carried out by traction on these capsule walls with cotton pledget stripping of the adjacent white matter. The removal of this triple-lobed abscess left a remaining hemispheric cavity that extended well forward under the parietal area, almost to the left occipital pole and into the major posterior two-thirds of the left temporal lobe. With such a sacrifice of underlying tissue a complete closure of the dura, including the original trephine defect, was easily accomplished. The scalp was sutured in the usual two-layer manner without drainage.

Bacteriology.—Gram-negative diplobacillus. Culture: *Bacillus influenzae*.

Postoperative Course.—The child's condition on leaving the operating room was extremely critical, although intravenous fluids and citrated blood had been administered throughout the procedure. Following a third transfusion the recovery from shock was satisfactory. Continuous intravenous Hartman's solution was maintained for three days. Sulfapyridine intravenously was administered (3 grains per pound body weight) daily for three days. On the seventh day after operation the child was able to take food, fluids and medicines orally. A blood level of sulfa, never below 21 mg., was maintained until May 27, a total of 18 days. On May 21, the lower end of the scalp wound began to bulge and a spontaneous rupture, with an abundance of purulent drainage, occurred. A drainage tube was easily inserted beneath the scalp. Into this tube a continuous drip of five per cent sulfanilamide solution was maintained. The tube was forced out of its subscalpular position by June 4, following which, complete granulation healing occurred. The child was discharged from the hospital on June 13, with normal speech, a right homonymous hemianopsia and a partial right hemiplegia. The paralysis had cleared by August, 1942, and the child has remained well since hospital dismissal. The illness, including the period of treatment extended over a period of 184 days.

COMMENT.—The problem which this patient presented was that the more orthodox neurosurgical procedures had been unsuccessful and, if a cure was to be effected, more radical efforts would be necessary. The lesion as outlined

by the thorium dioxide⁹ was visualized as being more posterior and considerably larger than the skull defect, so a larger bony exposure, with cortical uncapping to allow the lesion to "surface," was initially considered. With the hope that the preoperative fortification with sulfapyridine might prevent a meningitis or a spreading encephalitis, it was decided to extend the trephine opening to craniotomy-size and perform a total dissection of the lesion. The consistency of the capsule had been estimated from the duration of the illness and confirmed at the time of the injection of the contrast media. In the process of removing the overlying edematous cerebral cortex, the stalk of the abscess



FIG. 2.—The right hemiparesis and the absence of any cerebellar objective symptoms suggested a left temporoparietal abscess. The acquired symmetrical internal hydrocephalus outlined by ventriculography excluded this clinical location.

was opened with the cautery and the pus evacuated by suction. Although the capsule had been extremely resistant to the ventricular needle puncture, the wall proper was rather friable, so that its removal was somewhat in piecemeal. The cavity was entirely medullary white brain matter except for a small raw 1.5-cm. mass on its mesial wall. This was very firm to palpation and when punctured with an aspirating needle 20 cc. of pus was drawn into the attached syringe. This cavity was entered after the exposed projection had been opened (1 cm. core) with the cautery. It was possible to hold this capsule with the pituitary cup-forceps and dissect the entire sac except for what appeared to be a posterior attachment. This attachment was severed and the delivered capsule had 3-cm. openings on both ends. The "attachment" remaining proved to be a third cavitation of pus and when this had been opened, its contents

ABSCESS OF BRAIN

removed by suction and dissected free from the brain, there remained only a brain cavity surrounded entirely by the white matter.

The failure of the orthodox efforts might well be explained on the multilocular character of the abscess. The thorium visualization demonstrated the presence of but a single abscess and that one the most superficial. The initial aspiration (February 12, 1942) did improve the child's general condition but free drainage was necessary before any neurologic improvement occurred. It was reported that the amount of pus recovered at the time of the insertion of the first drainage tube was comparable to that amount which was aspirated 70 hours previously. The surgical efforts instigated prior to the radical dissection illustrate the long tedious difficulties that every one has had, at least once, in any worth while series of abscess experiences. The total period of illness to date of hospital discharge in this case was 184 days. The hospitalization of the radical abscess removal was 37 days.

Case 2.—A 12-year-old girl was taken ill, in April, 1942, with a complaint of bilateral earache. The left ear promptly began draining. Two weeks later mastoid pain on the left side appeared and the child's temperature became elevated above the normal. She was then given sulfa medication orally. Her temperature returned to normal after three days, but she began to complain of frontal headaches and there occurred early morning projectile vomiting. A spinal puncture was performed followed by symptomatic relief. On June 14, the headache and vomiting returned; the child complained of a photophobia and a diplopia. A brain abscess was suspected, and the child was referred for neurosurgical study.

Physical Examination.—June 21, 1942: The patient was a lethargic, listless child, whose physical appearance was very good. She consistently lay on her right side, shielding her eyes from the light. Neck flexion offered some pathologic resistance. Both optic nerve heads were swollen to four diopters elevation. There was a left external rectus palsy. There was a right facial weakness. The left arm and leg were more facile than the right extremities. All the deep reflexes were hyperactive. Roentgenograms of the skull were only pathologic for a left mastoid disease "with destruction of the left petrosal cells."

Ventriculogram—Aspiration of Abscess.—June 24, 1942: Frontally performed ventricle air injection outlined an acquired internal hydrocephalus of all the supratentorial cavities (Fig. 2). Following the ventriculogram the left occipital bone was trephined and a left cerebellar abscess was aspirated of 40 cc. of pus. Ten cubic centimeters of sulfanilamide solution was injected into the abscess cavity before the aspirating needle was removed.

Bacteriology.—Gram-positive coccus. Culture: Type-III pneumococcus.

Mastoidectomy.—June 30, 1945: Dr. Lester Brown performed a radical mastoid operation. Free pus was encountered when the petrosal tip was unroofed. The recovery from this was effective but the intracranial symptoms continued in a progressive manner.

Cerebellar Craniotomy—Dissection of Abscess.—July 17, 1942: A left unilateral suboccipital scalp flap was hinged inferiorly. The previous trephine opening was enlarged to a bone sacrifice of the entire left occipitocerebellar skull. The dura was reflected. A cerebellar cortical sacrifice of 2.5 cm. was made from the "stalk" of the previous aspiration site. The abscess was opened and its contents, of some 40 cc. of thickened pus, removed, by suction. Grasping the friable capsule with the cupped tissue forceps, folding it into the cavity made possible by the uncapping and aspiration, the mass was easily stripped from its engulfing cerebellar substance. This was accomplished by cotton pledget wedging dissection. The tip of the abscess, when removed, permitted identification of both the fifth and sixth cranial nerves. Three grams of sulfanilamide crystals were powdered into the remaining cerebellar cavity, the dura was resutured and the scalp closed in

layers without drainage. A 250 cc. citrate transfusion was administered, and the child left the operating theater in good physical condition.

Postoperative Course and Treatment.—There was a comfortable, gratifying convalescence. Sulfapyridine in three grain dosage per pound body weight per 24 hours, was begun on the first postoperative day and was continued for a total of 16 days. Free pulsations continued in the operative area throughout the remaining hospitalization. The mastoid wound had healed by August 1, and, on August 7, her neurologic symptoms and findings had disappeared. On this date she was discharged from the hospital, and she has remained well (Fig. 3).

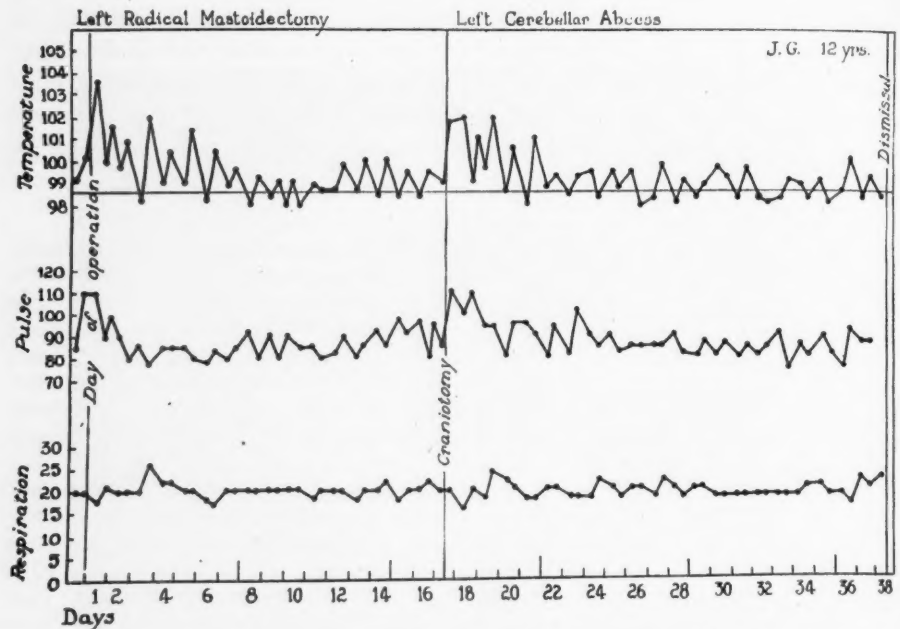


FIG. 3.—The clinical chart of the entire hospital period in Case 2.

COMMENT.—The increased intracranial pressure in this patient presented the most serious problem, so that following pneumoventricular localization, aspiration of the abscess appeared wiser in anticipating the radical mastoidectomy. This one fundamental in the treatment of brain abscesses is so important that a deviation from the purpose of this communication seems justifiable.

X Unless the focus of the abscess is abolished before, or at the time the brain abscess is treated, a cure may not be effected. A recurrence of the abscess is to be expected and, when the focus is within the bony structures, osteomyelitic processes are likely to develop. The aspiration in this case permitted an omission of any emergency efforts, and allowed effective convalescence from the petrosal infection. Further, it was demonstrated at the time of the craniotomy that in this particular case aspiration alone would not have been adequate treatment for a cure. Forty cubic centimeters of pus was removed at that time. Twenty-three days later, at the time of the craniotomy, an equal amount of pus was removed when the abscess cavity was opened. Both specimens con-

tained Type-III pneumococci. It is to be recalled that sulfanilamide had been injected into the abscess at the time of aspiration. The local application of sulfanilamide, undoubtedly, prevented an encephalitic-meningitic process, and allowed primary wound healing. The systemic sulfa therapy unquestionably complemented this topical treatment in obviating these infectious complications.

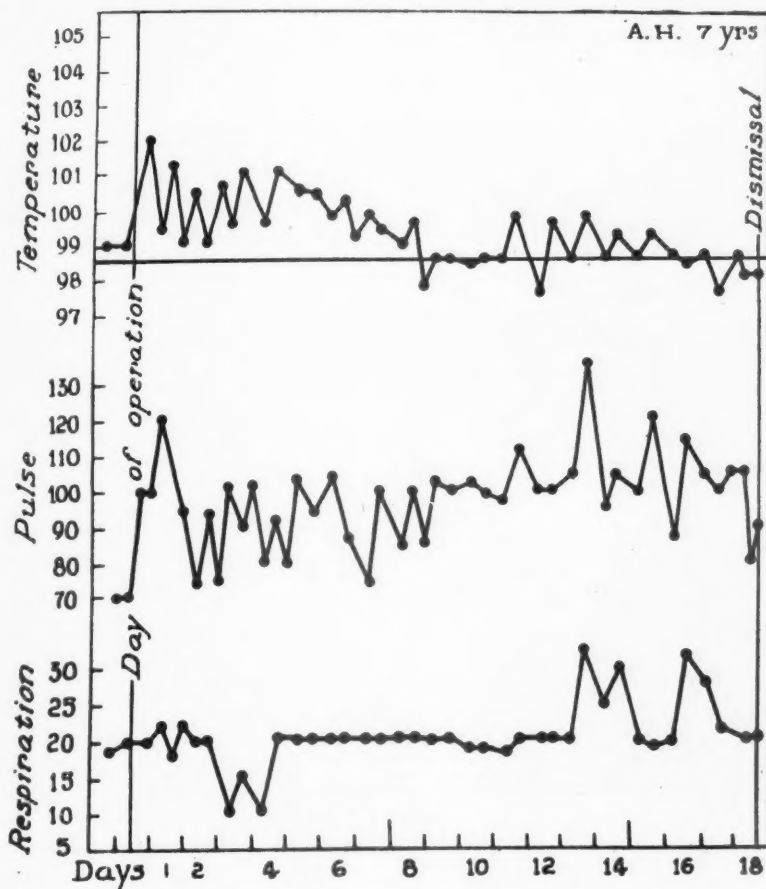


FIG. 4.—Convalescence was unmarred, and the patient was permitted to be out of bed on the 13th postoperative day.

Case 3.—A seven-year-old girl had the onset of her illness on December 18, 1943 with influenza. She was ill for four days and then began to have headaches. This was subsequently associated with a postural type of vertigo. She then developed generalized weakness and became rather listless, and there occurred a handicap in the use of her right arm and leg. Although she was normally right-handed she "preferred to use her left hand." January 25, an associated vomiting attended her more severe headaches.

Physical Examination.—February 4, 1944: Temperature 99.3°F. Pulse 110. She was very fretful and uncooperative. Physical development was very good. Bilateral choked disks and motor weakness of right arm and leg were noted. The abdominal reflex was absent on the right. There was generalized hyporeflexia without demonstrable pathologic reflexes. The right ear drum was injected and there was a tenderness over the right mastoid tip. Roentgenograms of the skull and mastoids were normal.

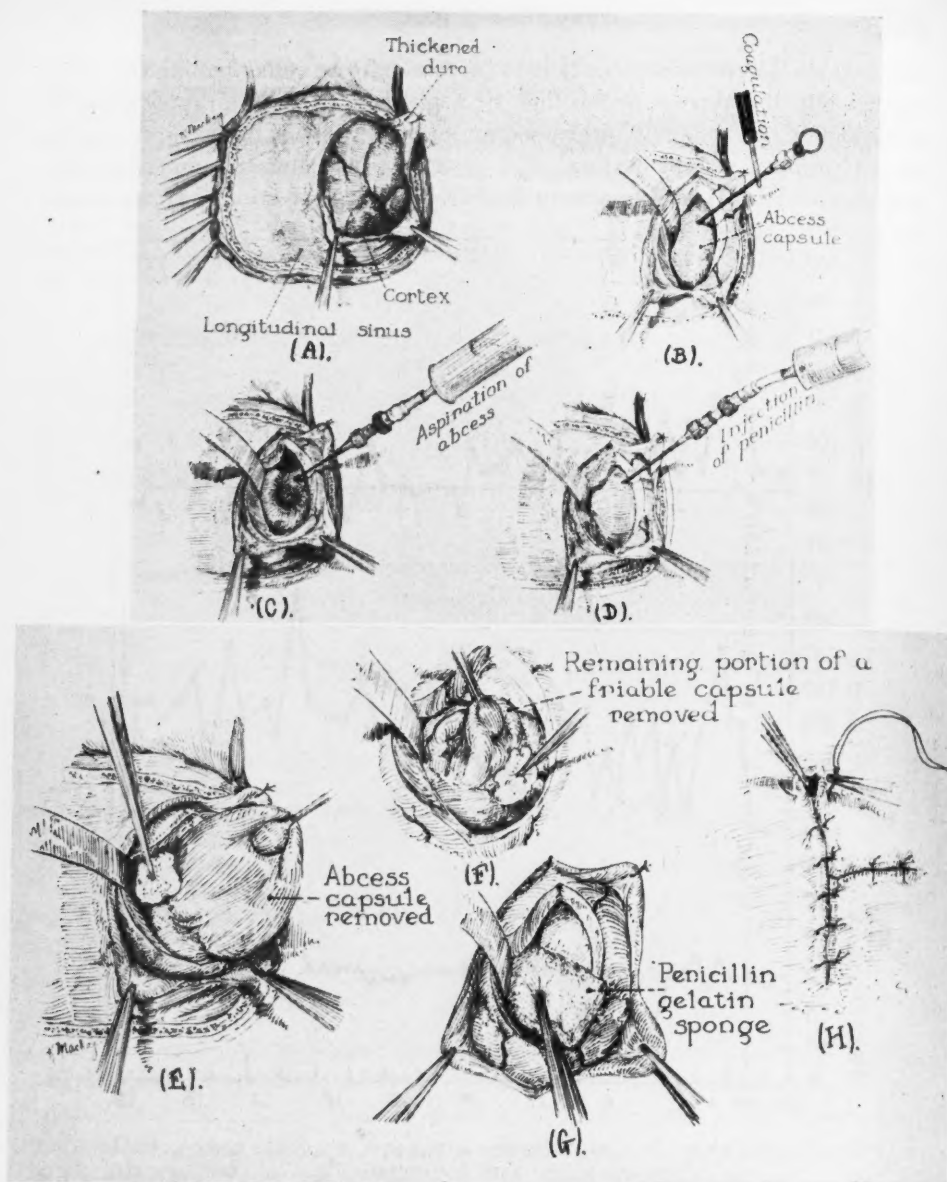


FIG. 5.—A. When the cortex has been exposed the depth of the abscess is determined by the exploratory ventricular needle.

B. The overlying cortex may be transected or a circumcisional uncapping performed to give an adequate exposure of the dome of the abscess. The exposed cortex and medullary brain are protected with cottonoid strips soaked in penicillin. The abscess is punctured under electrocoagulation.

C. Syringe aspiration of the cavity for gaining space for capsule dissection and for specimen collection minimizes wound contamination as compared with open suction methods.

D. The total amount of penicillin solution injected is for less than the volume of pus aspirated. The needle is withdrawn under electrocoagulation.

E. The small opening made by the aspirating needle is closed with the cupped forceps and, if possible, this traction-hold is maintained throughout the capsular dissection.

F. The friability of the abscess wall or the size of the lesion may necessitate piecemeal dissection. This is accomplished best with cotton pledget dissection, folding the abscess wall into its own cavity.

G. Gelatin sponge strips soaked in thrombin and then penicillin are placed in the medullary cavity. They are useful in sealing an opening into the ventricle cavity should such an accident occur in the dissection.

H. The dura is sutured tightly as in routine craniotomy following a tumor removal.

Ventriculogram.—February 4, 1944: Frontally performed ventricular air injection outlined a symmetrical dilation of all of the ventricular cavities above the tentorium.

Cerebellar Craniotomy—Dissection of Abscess.—February 4, 1944: Through a cross-bow exposure the cerebellum and first cervical spinal cord level was exposed. The right cerebellar lobe was full and the lamellae broadened. An exploratory needle introduced into this hemisphere encountered a resistance 1.5 cm. from the cortex surface. This resistance was that of a tennis ball. A split was made in the cortex and the surface of a soft demarcated mass was inspected. The upper outer one-third of the cerebellar cortex was then sacrificed, exposing a domed mass for an area of 2.5 cm. A ventricular needle was introduced into the cavity of the mass with the aid of electrocoagulation. As the stylet



FIG. 6.—The clear-cut ventricular deformity of the right cavity suggested a demarcated rather than an infiltrating lesion as was clinically suspected.

from the needle was withdrawn, syringe suction was immediately applied to the end of the needle and no free pus allowed to soil the exposed field. After a collapse of the abscess from suction, the opening was closed with the pituitary cup-forceps, and this hold on the abscess capsule gently maintained throughout the dissection. With cotton pledget wedging dissection the adjacent cerebellar substance was detached from the pathologic lesion. To gain room for the continued dissecting process it was necessary to reinsert the aspirating needle through the original puncture wound as it was necessary to aspirate the pus on two subsequent efforts. The final dural attachment of the capsule was at the petrosal dura. A four-centimeter cavitation was left when the entire abscess wall had been removed. Two grams of sulfanilamide was sprinkled into the bottom of the cavity and an additional 25,000 units of penicillin was injected into the same area. The dura was closed tightly, as were the muscle layers, deep and subcutaneous fasciae. Two hundred and fifty cubic centimeters of citrated blood was given intravenously, and the child's condition was most satisfactory upon completion of the operation.

Bacteriology.—A gram-positive coccus. Culture: *Streptococcus viridans*.

Postoperative Course and Treatment.—Sodium sulfadiazine in normal saline (2.5 gm. in 500 cc.) was administered intravenously each day for three days. She was then given one gram of sulfadiazine by mouth every four hours for the ensuing ten days. The skin sutures were removed after 96 hours. She was out of bed, walking, with no handicaps, on February 20, and was discharged from the hospital on the 22nd, after a total of 22 days hospitalization (Fig. 4). She has remained well.

COMMENT.—This case illustrates the technical maneuvers that were utilized in this and the subsequent two cases (Fig. 5). Completely, to uncap an underlying abscess for an area equal to the greatest diameter of an abscess would always require a sacrifice of a very large area of overlying brain tissue, but by exposing the dome of the abscess (in this case a 2.5-cm. sacrifice) adequate room for aspiration, for grasping the capsule and for dissection is available. The surrounding brain tissue is walled-off with penicillin-soaked cottonoid strips, the distal ends of which are gently inserted between the abscess wall and the adjacent medullary brain tissues. A 3-mm. spot is coagulated on the dome of the abscess and, with the aid of electrocoagulating current, the abscess cavity is punctured with the ventricular needle. Allowing no free pus to spill into the wound, aspiration of the cavity for its full contents is accomplished by syringe suction. This fluid collection is for bacteriologic studies and for a measurable estimate of the size of the cavity. Without removing the needle, once the cavity has been emptied, penicillin is injected into the cavity, the stylet of the needle reinserted and the needle withdrawn under electrocoagulation just in the manner that it is inserted. The needle opening is closed by grasping the now flabby capsule with the cupped tissue forceps. It is desirable that this hold be maintained, but tissue age does not always permit this. If an uncapping of the cavity is done, owing to the friability of the abscess wall, the cup-forceps still remain effective in allowing mild traction on the abscess wall. This is accomplished by having one cup inside the cavity and one outside. With this traction, placing the cottonoid strips deeper as cotton pledget dissection forces the surrounding white matter away from the abscess wall, one encounters no hemorrhage from this bed. Once beneath the greater diameter of the abscess one finds the strips and the intracranial pressure delivering the sac or its final remnants to the surface. Gelatin sponge strips are placed in the rapidly narrowing remaining cavity. The technicalities, from here on, are those of any clean craniotomy, namely, tight closure of the dura, suturing of the osteoplastic flap and layer closure of the scalp without drainage.

Case 4.—A 47-year-old farmer dated the onset of his sickness from January, 1945, at which time a diagnosis of malaria was made. This illness consisted of one chill and one temperature elevation, and the treatment consisted "of three days of sulfa drugs." In February, early morning headaches developed. These were frontal in location, a bit more severe on the right side and infrequently associated with vomiting. Soon after the onset of headaches, he began to stagger, and usually to the left side. There followed a photophobia, a diplopia and a failing memory for recent events.

Physical Examination.—April 30, 1945: The patient was a coöperative, fairly alert adult. Both optic nerves were elevated some three diopters. There was a left facial weakness of central type. There was an incoördination in the use of the left arm and leg.

ABSCESS OF BRAIN

There was a left homonomous visual field defect. Routine roentgenograms of the skull were only significant in that the pineal calcification was shifted to the left.

Ventriculogram.—May 3, 1945: Frontally performed ventricle air injection depicted a space-occupying lesion in the right posterior temporal area (Fig. 6).

Right Temporal Craniotomy.—May 3, 1945: Through a left temporal osteoplastic flap the volume of the right temporal lobe was exposed. The intracranial pressure was so increased that no free cerebral pulsations were visible or palpable. An exploratory cannula was introduced into the brain substance in the posterior part of the midtemporal convolution and a characteristic resistance was encountered 2 cm. from the cortex surface. With electrocoagulation this resistance was punctured and the stylet of the cannula was removed. Two ounces of pus was aspirated. Penicillin (100,000 units) was injected into the abscess and again with electrocoagulation the cannula removed. Free cerebral pulsations were thus

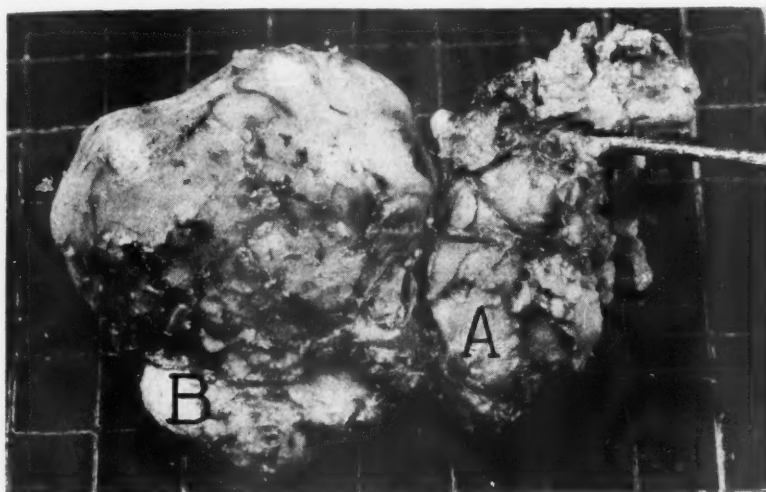


FIG. 7.—The specimens photographed on a centimeter-squared background show the elliptical "cortex cap," A, which sacrifice was necessary to expose the dome of the large abscess, B.

established and the dura was reflected for the area of its exposure. The midtemporal convolution was broadened and pale. A 3-cm. circumcision (Fig. 7A) was made about this convolution and at a depth of 2 cm. in the white matter the smooth dome of the granulation mass was displayed. With cotton pledget-wedging maneuvers the capsule was caught with the cupped forceps. It was too friable for worth while traction so that the dome was excised with the electric current. By folding the walls of the abscess into its own cavitation and with gentle retraction, complete freeing of the base was permitted (Fig. 7B). During this dissection, on the mesial surface of the abscess, a small opening was made into the lateral ventricle. The bleeding from the surrounding medullary brain substance was indeed minimal. Three grams of sulfanilamide crystals was sprinkled into the bed of the intracerebral cavity. Gelatin sponge strips soaked in penicillin were placed in the bed of this cavity and along its walls. The dura was sutured tightly. Two grams of sulfanilamide were placed outside the dura, the bone flap sutured *in situ* and the scalp closed without drainage.

Bacteriology.—Culture: *Staphylococcus aureus*.

Postoperative Course and Treatment.—The convalescence was not marred by any disturbing upsets. Penicillin (25,000 units) was administered intrathecally every other day for five doses. Intramuscular penicillin was administered every three hours for six days. The highest cell count in the spinal fluid was 509 cells per cubic centimeter from five

studies, and no organisms were cultured from any of these specimens. The patient was permitted out of bed on the 11th day after operation, and discharged, May 21, after a total of 21 days hospitalization. Seen on September 28, the patient was feeling "quite normal," there were no residual palsies, but there was a complete left homonymous hemianopsia.

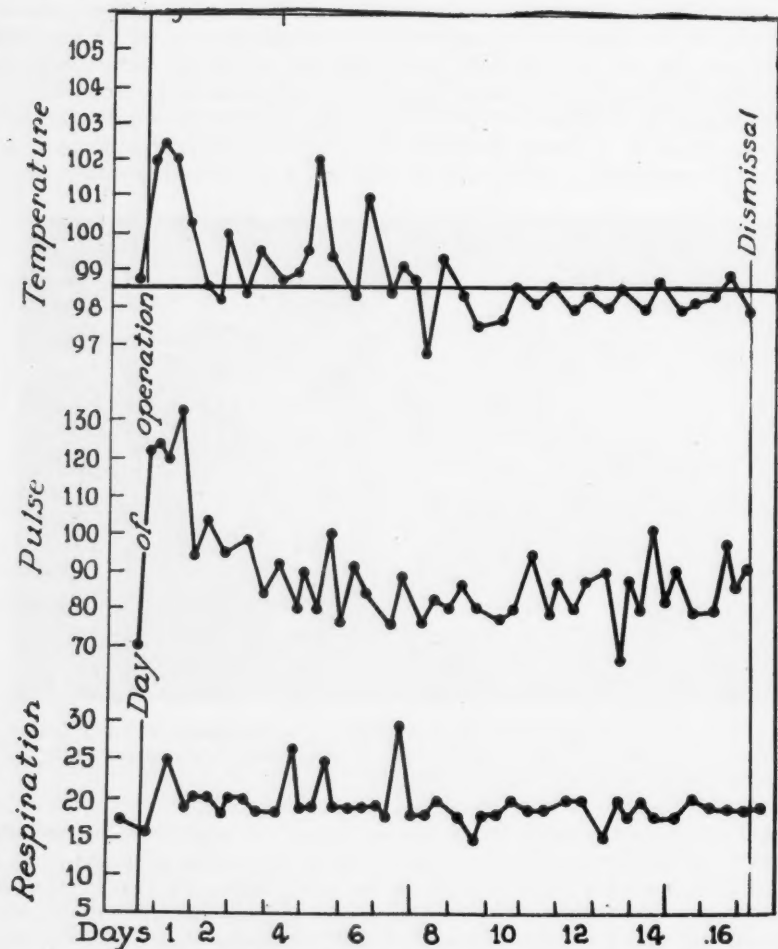


FIG. 8.—This clinical chart could be substituted for any normal convalescent craniotomy in which a benign tumor might have been removed.

COMMENT.—The infectious history in this case was obtained after the pathologic diagnosis had been made. He was considered clinically as a right temporal lobe tumor and, on account of the short history, an histologic diagnosis that his "tumor" was a glioblastoma was made. The ventriculographic depiction was more that of a "demarcated space-occupying lesion" than "that of an infiltrating one." Still, with a tumor diagnosis following the ventricular studies, an osteoplastic flap cortex exposure was performed. There being no lesion visible on the surface, the exploring ventricular needle was utilized. The resistance met by it was the rather characteristic rubbery resistance of an

ABSCCESS OF BRAIN

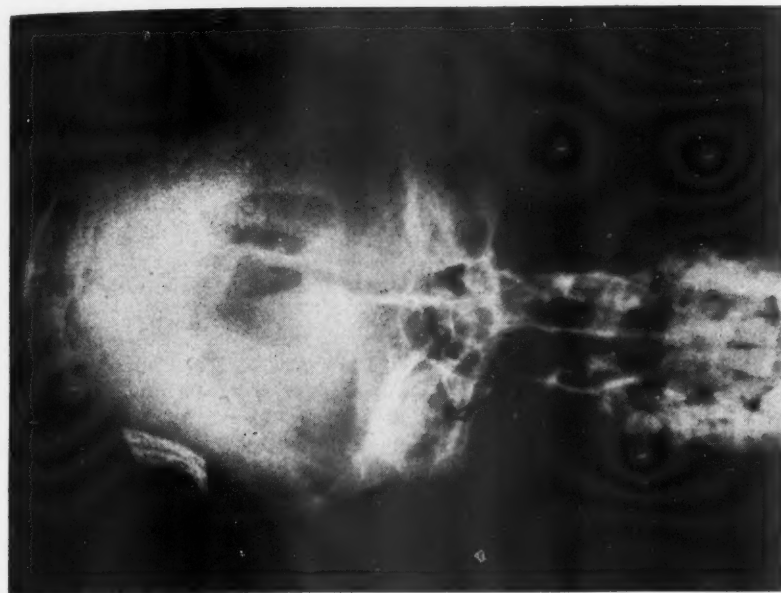


FIG. 10.—The localization in this case was dependent on the defective right anterior ventricle deformity. These studies were performed after radical excision of the osteomyelitis.



FIG. 9.—The rarefaction of the frontal bones is the radiologic characteristic of osteomyelitis. Note the loss of the detail of the frontal sinus outline on the right side.

abscess, so that an electrocoagulation puncture was made into the abscess cavity. The technical procedures instituted here were those already referred to, and were enforced in every detail. Although the personal experiences of the author, as well as those of many neurosurgeons, before the introduction of sulfa and penicillin therapy, in situations of this type would have prompted a malign prognosis, the experiences in Cases 1, 2, and 3 permitted a more optimistic outlook. The convalescence was that of a normal craniotomy from which a benign tumor had been totally removed.



FIG 11.—Although the volume of pus was evacuated during the dissection, when the operative split was opened for photographic detail there still remained a few cubic centimeters.

bones were diseased. All grossly infected bone was removed. This left a defect some 7 cm. in diameter. Bilaterally, there were epidural granulations. There were no free cerebral pulsations demonstrable on the right or left side of the exposed sagittal sinus. Penicillin-soaked gelatin sponge strips were laid over the exposed dura. The old scalp incisional sinuses were excised and the scalp was closed in layers without drainage. The wounds healed by primary intention.

Ventriculogram.—August 21, 1945: Posteriorly performed ventricular air injection outlined a large right frontal horn filling defect (Fig. 10). There was a displacement of the superior portion of the anterior third ventricle to the left.

Craniotomy.—August 21, 1945: The previously performed scalp flap was reflected. The granulating dural surface showed no evidence of gross infection. The dura on the right side was opened for the limit of the bone exposure and to the longitudinal sinus, on the mesial side. The convolutions exposed were broadened, bulged above the dural level, and evidenced no free pulsations. An exploratory needle into the anterior pole of the right frontal lobe encountered a resistance 1.5 cm. from the surface. A 2-cm. sacrifice of the cortex was circumscribed and the abscess dome bulged into the exposure. The abscess was aspirated of 15 cc. of its pus, and cupping the aspiration opening the capsule was retracted. With cotton pledget dissection and aided by the intracranial pressure, a 3.5-centimeter mass (Fig. 11) was delivered as one would such an intracerebral tumor. The hemorrhage from the bed of the dissection was very mild and easily controlled with

Case 5.—A 17-year-old boy, in June, 1945, developed a small swelling in the right frontal area, just above the eyebrow. He was told this was a "cyst." This was incised and pus obtained. This continued to drain, and a similar "cyst" developed over the left frontal area. This too was incised with purulent drainage. In the latter part of July a diplopia developed which was his chief complaint at the time of hospital admission.

Physical Examination.—August 10, 1945: There were encrusted draining wounds in the frontal area. There was a bilateral choked disk of four diopters. There was a left sixth nerve paralysis. There were no other neurologic objective symptoms. Roentgenograms of the skull depicted an osteomyelitis of the frontal bone (Fig. 9).

Radical Excision Osteomyelitis — Bifrontal.—August 14, 1945: A horseshoe-shaped flap was reflected down over both orbital ridges. The right and left frontal

ABSCESS OF BRAIN

bovine thrombin applied with the gelatin sponge packs. These strips were also soaked in penicillin. A total of 100,000 units of penicillin was left within the medullary cavity. The dura was closed tightly. Two grams of sulfanilamide crystals were powdered over the dura, and the scalp was closed in two layers with interrupted black silk sutures.

Bacteriology.—Smear from osteomyelitic skull: Gram-positive cocci. Culture: *Hemolytic Staphylococcus aureus*. Culture brain abscess: *Hemolytic Staphylococcus aureus*.

Postoperative Course and Treatment.—Sulfadiazine, 1 gram every four hours, was given by mouth for eight days. Intrathecal penicillin was given in 25,000 unit dosages



FIG. 12.—Photographed 20 days after abscess removal, healing *per primam* occurred as did this same wound after the radical sacrifice of the osteomyelitis. The stab wounds are the débrided incisions of the former "cyst" operations.

every 48 hours, for four treatments. The highest cell count in these four specimens studied was ten lymphocytes. By September 3, primary wound healing had occurred (Fig. 12), the diplopia had disappeared and the choking of the optic disks was subsiding. He was discharged from the hospital, September 17, 38 days after admission.

COMMENT.—This case doubly illustrates the value of chemo-penicillin as a vital adjunct to neurosurgery. The osteomyelitis was surgically eradicated, the infected dural granulations were covered with gelatin sponge strips saturated first with bovine thrombin, then with penicillin. These strips served not only as carriers for the coagulant material and the antibacterioidal agent, but served

to obliterate the dead space made necessary by sacrificing the diseased skull. When this wound was reopened seven days later there was no serum collection or gross pus, and healthy granulations were covering the dural exposure throughout. Twenty-seven days after the total removal of the brain abscess the patient was dismissed from the hospital.

TABLE I

Case	Operation	Location	Bacteriology	Treatment		Hospitalization	
				Local	Systemic	Total Days	Days after Craniotomy
I.	Decompression craniotomy	Left temporal	<i>Bacillus influenzae</i>	Sulfanilamide	Sulfapyridine	184	35
II.	Ventriculography radical mastoid. Craniotomy	Left cerebellum	Type III pneumococcus	Sulfanilamide	Sulfapyridine	48	18
III.	Ventriculography. Craniotomy	Right cerebellum	<i>Streptococcus viridans</i>	Sulfanilamide	Sulfadiazine	22	22
IV.	Ventriculography. Craniotomy	Right temporal	<i>Staphylococcus aureus</i>	Sulfanilamide Penicillin	Sulfadiazine Penicillin	21	17
V.	Radical osteo. Ventriculography Craniotomy	Right frontal	<i>Hemolytic staphylococcus aureus</i>	Sulfanilamide Penicillin	Sulfadiazine Penicillin	38	27

The results from the reports in the literature on brain abscesses that have been removed *in toto* have been surgically ideal. These wounds have healed by primary intention, and these patients have escaped the prolonged hospital complications and often fatal results that have followed all other methods of treatment. The follow-up details in these *intact* extirpations are too inadequate to evaluate with any degree of accuracy the latent sequelae, namely, convulsions that have developed following aspiration, drainage, or uncapping methods. In the five cases here reported where radical total dissections have been carried out, aided by sulfa and penicillin therapy, the hospitalization (Table I) period has been comparable to that of a normal convalescence period of any craniotomy and the morbidity, with one exception, has been *nil*. As to latent sequelae, a continued observation will be maintained. The results thus far have been such as to suggest that the basic surgical principle of "incision and drainage" in the treatment of certain abscesses of the brain might be replaced by total abscess dissection and primary wound closure.

REFERENCES

- ¹ Sargent, Percy: Drainage of Brain Abscess. *Brit. M. J.*, **2**, 271, 1928.
- ² Vincent, C., David, M., and Askenasy, H.: Sur une methode traitement des abces subaigus et chroniques des hemispheres cerebraux. *Rev. Neurol.*, **49**, 1, 1937.
- ³ Odum, Guy L., and Elvidge, Arthur R.: Surgical Removal of Brain Abscess Due to *Bacillus Typhosus* Following Typhoid Fever. *Arch. Neurol. & Psych.* **48**: 465, 1942.
- ⁴ Groff, Robert A., and Grant, Francis C.: The Surgical Treatment of Brain Abscess by Exposure and Enucleation. *ANNALS OF SURGERY*, **107**, 925, 1940.

ABSCCESS OF BRAIN

- 5 Rowe, Stuart N.: Sulfanilamide in Brain Abscess. *ANNALS OF SURGERY*, 107, 620, 1938.
- 6 Bucy, Paul C.: Sulfanilamide in Treatment of Brain Abscess and Prevention of Meningitis. *J. A. M. A.*, 18, 1639, 1938.
- 7 Walker, Exum: Use of Penicillin in a Case of Multiple Brain Abscess. *Hawaii*, 4-1, p. 24, 1944.
- 8 Furlow, Leonard T.: Penicillin as an Adjunct to Surgery in the Treatment of Brain Abscess. *South. M. J.*, 38-5, 312, 1945.
- 9 Kahn, Edgar A.: Contrast Media in Cysts and Abscesses of the Cerebral Hemispheres. *Surg. Gynec. & Obst.*, 74, 983, 1942.

DISCUSSION.—DR. EDGAR F. FINCHER, Atlanta, Ga.: When Doctor Pilcher wrote me of his heroic efforts I could only say I thought he was extremely courageous.

There are many details in his manuscript that must be read to properly appreciate this contribution. In the attempt to discuss it, I find myself stymied by first, an extremely limited experience; and, second, some rather hair-raising mental gymnastics, as I recall, at the operating table when these few experiences were encountered. I think the younger neurosurgeon would do well to read and strictly adhere to Doctor Dandy's publication in 1928* the evening before he plans a craniotomy attack on these lesions.

I can only reemphasize the main indications for operation on these patients: (1) That the lesion be remote in its location to the motor cortices or the left temporal lobe of a right-handed person; (2) that repeated dangerous spontaneous hemorrhages must have occurred; and (3) that uncontrollable convulsions constitute a primary handicap.

I am sure we are cognizant of the fortitude displayed by Doctor Pilcher in his surgical attack in these three cases and will, by virtue of his efforts, be encouraged to offer some hope for those individuals whose lesions meet the afore-mentioned criteria.

DR. WALTER E. DANDY, Baltimore, Md.: If one were looking for the ultimate test of a surgeon's skill, it would be in cases such as this. These are the most vicious lesions in the brain, without any question. His first case is a type that anyone should extirpate; it is in the right occipital lobe where only a hemianopia will result. And the subsequent absence of convulsions has justified his judgment. The extirpation in his second case was practically forced upon him, and a surgeon of less skill would certainly have lost the patient.

I have had only one complete extirpation of such a lesion. One must remember that these lesions are fed by one, sometimes two arterial branches, and from these the blood passes directly into veins or coils of vessels without an interposed capillary bed. The trick of removing these lesions is to go through the brain beyond the lesion and ligate the artery that feeds it. When that is done there will be almost no bleeding.

Certainly Doctor Pilcher deserves a great deal of credit for his fortitude and skill.

In his second case he was fortunate that it was fed by the anterior artery, not by the middle cerebral artery. There are three arteries from which the arterial blood enters the aneurysm, the anterior, middle and posterior cerebral. Those fed by the posterior cerebral are much the easiest to extirpate.

About Doctor Sachs' paper: I think he might have approached this problem in a different light and thereby have been more instructive. Abscesses vary so much in the organisms that cause them, and the results are dependent on the causative organism. So many are multiple, and that complicates the situation. Some are metastatic, others arise by direct extension. The most common organisms are *Staphylococcus aureus* and *Streptococcus*; these are more than half the total number. Single abscesses due to these organisms are easily cured by a single tap and without aspiration or drainage. Following that the abscess resolves and gradually shrinks; in other words, nature takes care of it. With other abscesses the problem differs with the organisms involved; but tapping will not cure them. If the abscesses are multiple the problem is again different and requires more than tapping.

Doctor Fincher has some nice results with extirpation. I have done several when I have encountered them unexpectedly, and with success in most of them. I can recall,

* Arch. Surg. Vol. 17, p. 190.

however, one patient who had complication after complication and finally succumbed. Extirpations are still dangerous despite penicillin. My feeling about abscesses is to do the least possible.

DR. ERNEST SACHS, St. Louis, Mo.: Quite a number of years ago I presented, before the American Neurological Association, a series of these lesions and called them intracranial telangiectases. I felt that they were not tumors—new growths. A number of these cases we have treated by methods different from Doctor Pilcher's. What we have done was to use a very low coagulating current and coagulated the entire lesion without extirpation. But it may be that the courageous procedure Doctor Pilcher used is more effective. Certainly, in our six or seven cases the coagulation method was effective.

Regarding Doctor Dandy's criticism, I have only this to say: In reviewing this rather large series of brain abscesses I was forced to the conclusion that extirpation was satisfactory except in cerebellar cases, and I feel sure that the ideal thing, if you have any capsule at all, is to extirpate the entire lesion.

DR. J. E. J. KING, New York, N. Y.: I want to congratulate Doctor Pilcher on his work in this group of cases and on his good results. I have seen and operated upon two cases with this condition, both being for the most part in the parietal region, and both in appearance "dead ringers" for one case especially, reported by Bronson Ray several years ago. Considering the location, it was inadvisable to extirpate either; one was partly coagulated followed by roentgenotherapy, and in the other roentgenotherapy alone was used. The latter case was that of a Negro with considerable weakness in his right hand. The last information I had from him was that he was earning his living working in a war plant.

I wish to thank Doctor Sachs for his splendid report. He has had an enormous experience. I agree with everything he stated and the manner in which he said it. One of the outstanding thoughts he left with us is that he attempts to save life regardless of what the patient's condition may be; in other words, he tries to save life regardless of what statistics may show.

With reference to Doctor Fincher's paper, I should like to say that I agree heartily with him that the original focus of the disease should be completely eradicated prior to operation for the brain abscess. I have had two cases in which the patients died from reformation of an abscess after the original abscess was well under control. The two abscesses in each case resulted from an old original extracranial focus which had not been properly operated upon.

Regarding brain abscess, in general, the ideal situation is not to have one at all. Great progress in this direction has resulted from the use of the sulfonamides and penicillin, and the incidence of brain abscess has been greatly reduced thereby. At the present time we do not see so many of these cases as heretofore.

In the past several procedures were carried out by various men, and each justified its use, for a number of cures have been effected by each method. The intention of any procedure, of course, is to get rid of the pus and abscess, prevent spreading into the meninges or ventricles, effect a cure, and prevent recurrence. Penicillin and the sulfonamides have just about "licked" meningitis. The results in the war have been magnificent so far as early injuries of the brain are concerned, and to a large degree are attributed to the proper use of these two drugs. All the information given me by former associates and personal friends confirms the opinion about the effects of these drugs in head injuries. It is well known that during World War I Doctor Cushing, with his most meticulous type of surgery, was not able to reduce the mortality rate lower than about 27 per cent, and prior to his type of surgery the mortality rate was in the neighborhood of 60 per cent, or greater.

Doctor Fincher, no doubt anticipating the intentions of a number of us, has advanced the problem supported by his knowledge of what these drugs will accomplish. In my opinion he has presented the very best procedure for operating upon brain abscesses where it can possibly be done. What could be more logical and sensible than to localize the abscess and remove it *in toto*, if possible, or piecemeal if necessary, just as one would a meningioma? It goes without saying that one cannot deal with all abscesses in this manner, but this solution is, without doubt, the one most of us have been hoping for. Doctor Fincher has proved its efficacy.

ABSCESS OF BRAIN

I heartily agree with him in the establishment and maintenance of the sulfa blood level and the local and intrathecal use of penicillin. In my recent experience they have proved to be good. I can recall five or six patients operated upon before the era of sulfonamides and penicillin who, I feel sure, could have been saved with the use of these drugs. More words in praise of Doctor Fincher's paper could be said, but time does not permit. He is to be highly commended for his splendid work and excellent presentation.

DR. CLAUDE C. COLEMAN, Richmond, Va.: After I have expressed my admiration for Doctor Pilcher's skill and heroic operations upon aneurysms of the brain, I should like to discuss briefly the papers of Doctors Sachs and Fincher. I have always felt that the eradication of a brain abscess should be accomplished with the least possible disturbance to the surrounding brain. Some years ago I reported 26 consecutive cases of abscess with four deaths. All these patients were treated by catheter drainage. However, I think we are prone to change our attitude toward the treatment of brain abscess and I think we should be prepared to do so. Abscesses occur in different locations with different organisms. I have had prompt recovery with simple tapping of an abscess as advocated by Doctor Dandy. In most of the cases when the patient did not show improvement after tapping or if there were progression of symptoms, I have usually attempted to insert a small drain. It seems to me the more radical treatment advocated by Doctors Sachs and Fincher should be reserved for those cases that resist simple methods of treatment. I have removed such abscesses *in toto*, with their capsule, after failing to cure them by tapping and drainage. I think there is a good deal to be said for the radical extirpation, with the capsule, in multiple abscesses or in those in which a large granulomatous mass forms which cannot be eradicated. It seems best that one should be prepared to use more than one procedure, dependent on the abscess.

Doctor King, who has had a large experience in the treatment of abscess, states he does not see as many of them as formerly. This is true in my experience. With better eradication of mastoid and frontal sinus infection, and with the use of the sulfonamides and penicillin, brain abscesses should become more rare. With these drugs and the proper handling of suction, I believe one can use the procedure advocated by Doctors Sachs and Fincher with very much more chance of success than was formerly possible.

STREPTOMYCIN IN URINARY INFECTIONS*

MAJOR BORIS P. PETROFF, M.C., A.U.S.,

AND

2ND LIEUT. FRED V. LUCAS, SN.C., A.U.S.

THE UROLOGIC PROBLEM IN PARAPLEGIA is that of urinary infection, which takes place when catheter or suprapubic drainage are instituted. Mixed infection results which first involves the lower urinary tract in the form of cystitis and urethritis often accompanied by epididymitis and periurethral abscess, and then migrates to upper urinary tract with resultant pyelonephritis, cortical abscesses and in some cases formation of calculi.

A total of 87 patients (with neurogenic bladders due to involvement of central nervous system) have been admitted to Newton D. Baker General Hospital since October, 1944, of whom 77 were paraplegias due to spinal cord injuries. Forty of these had suprapubic cystostomies and heavily infected urine.

TABLE I

BACTERIA FOUND IN PARAPLEGIC BLADDERS

A Aerogenes	39%
Colon Intermediate	18%
B Proteus	15%
Paracolon	12%
B Pyocyaneus	8%
Staph Aureus	5%
Alpha Strep	3%

The balance were emptying their bladders spontaneously but were also infected. The suprapubic cystostomies were changed over to urethral catheters, allowed to close and placed on tidal drainage, using Suby and Albright's M solution (citric acid buffered solution) having a p_H of 4.5.

Urine cultures showed a mixture of organisms, gram-negative bacilli and gram-positive cocci. The gram-negative bacilli were predominant (Table I).

Between October, 1944 and April, 1945, despite all aseptic precautions in the use of tidal drainage, each patient had an average of one to three elevations of temperature a month, often attended by chills. There were eight cases of renal calculi of which one was bilateral, nine epididymites, eight periurethral abscesses, three positive blood cultures of *Aerobacter aerogenes* and *Bacillus proteus*, and there was one death due to cortical abscesses infected with *A. aerogenes*.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

Streptomycin Treatment for Infection with Gram-Negative Bacteria in Voiding Neurogenic Bladders with Upper Urinary Tract Changes

CASE	AMOUNT AND DOSAGE OF STREPTOMYCIN	LOT NO.	REACTIONS	BACTERIA IN URINE BEFORE TREATMENT	TREATMENT	BACTERIA 24-48 HRS AFTER TREATMENT	TREATMENT	BACTERIA 4-7 DAYS AFTER TREATMENT	LEVELS IN URINE OF STREPTOMYCIN 6 HRS AFTER START	URINE	BLOOD	URINE	BLOOD
1. Ho. Residual 180cc Nephrectomy Stone	200,000 Units 1 M. + 100,000 Q 3 Hrs. Total 500,000 in 12 Hrs.	212	None	A. Aerogenes	A. Aerogenes	A. Aerogenes	A. Aerogenes	A. Aerogenes	31.7	3.5	29.6	5.0	
2. Kir. Kidney and Urethral stone	" " " " " "	212	None	A. Aerogenes Staph. Aureus	Sterile	Sterile	B. Pyocyanus Staph. Aureus	B. Pyocyanus Staph. Aureus Fewer colonies	34.8	—	27.0	—	
3. Ho. Residual Urine 180cc	200,000 Units 1 M. Repeated Q 3 Hrs. Total 1,000,000 in 15 Hrs.	187	Headache	A. Aerogenes	A. Aerogenes	Sterile	A. Aerogenes	A. Aerogenes Fewer colonies	28.0	11.3	21.8	4.0	
4. San. Bilid Ureter Relaxed Sphincter	" " " " " "	187	Headache Joint pains Temp 101.4 F	A. Aerogenes B. Proteus	A. Aerogenes	Sterile	B. Proteus	B. Proteus Staph. Aureus Fewer colonies	30.5	4.0	52.0	13.0	
5. Kir. Ureteral stones	" " " " " "	187	Headache	A. Aerogenes B. Proteus Staph. Aureus	A. Aerogenes	Sterile	A. Aerogenes B. Proteus Fewer colonies	A. Aerogenes Fewer colonies	25.5	—	22.0	—	
6. Pl. Relaxed Sphincter	" " " " " "	187	None	A. Aerogenes	A. Aerogenes	Sterile	Staph. Aureus Hem. Few colonies	Staph. Aureus Hem. Few colonies	22.0	4.0	31.0	1.0	
7. We. Relaxed Sphincter	" " " " " "	187	Headache Joint pains	A. Aerogenes	A. Aerogenes	Sterile	B. Proteus Fewer colonies	B. Proteus Fewer colonies	22.0	1.8	25.5	3.0	
8. Po. Residual Urine 60cc	" " " " " "	187	None	B. Proteus Para colon E. Coli Staph. Aureus	Sterile	Sterile	Staph. Aureus fewer colonies B. Proteus	Staph. Aureus fewer colonies B. Proteus	22.0	1.0	—	—	
9. Ek. Relaxed Sphincter Incontinence	" " " " " "	187	None	A. Aerogenes	A. Aerogenes	Sterile	B. Pyocyanus Colon Intermediate t. Berthella Dubia Staph. Albus	B. Pyocyanus Colon Intermediate t. Berthella Dubia Staph. Albus	27.0	1.2	21.5	1.5	
10. Br. Residual Urine 200 cc	" " " " " "	187	Headache	A. Aerogenes B. Proteus	A. Aerogenes	Sterile	A. Aerogenes	A. Aerogenes	52.0	8.0	47.0	3.8	
11. Ja. Relaxed Sphincter Incontinence	200,000 Units 1 M. and 100,000 U Q 3 Hrs. Total 1,000,000 in 24 Hrs.	226	None	A. Aerogenes B. Proteus Staph. Albus E. Coli	2 colonies A. Aerogenes Few B. Proteus Staph. Albus	A. Aerogenes B. Proteus Staph. Aureus	A. Aerogenes B. Proteus fewer colonies	A. Aerogenes B. Proteus fewer colonies	36.0	2.8	42.0	—	
12. Kr. Relaxed Sphincter	" " " " " "	226	None	A. Aerogenes B. Proteus Staph. Aureus	A. Aerogenes B. Proteus Fewer colonies	Staph. Aureus B. Proteus Fewer colonies	Staph. Aureus B. Proteus fewer colonies	Staph. Aureus B. Proteus fewer colonies	29.6	—	21.5	1.0	
13. Ki. Residual Urine Bladder stone	" " " " " "	212	None	B. Proteus	B. Proteus	B. Proteus Fewer colonies	B. Proteus Fewer colonies	B. Proteus	37.0	6.0	29.5	1.0	

Table II.—Table of 13 cases.

Streptomycin Treatment for Infection with Gram-Negative Bacteria
 In Neurogenic Bladders on Catheter Drainage and with Upper Urinary Tract Changes

CASE	AMOUNT AND DOSAGE OF STREPTOMYCIN	LOT NO.	REACTION	BACTERIA IN URINE BEFORE TREATMENT	BACTERIA 24- 48 HRS AFTER TREATMENT	BACTERIA 4- 7 DAYS AFTER TREATMENT	LEVELS IN UNITS OF STREPTOMYCIN			
							6 HRS AFTER START	12 HRS AFTER START	12 HRS AFTER 5 DAYS	12 HRS AFTER 5 DAYS
							Urine	Blood	Urine	Blood
1. Sn. Ureth. Cath. Catheter	200,000 Units 1 M + 100,000 U. 93 Hrs. Total 300,000 in 12 hrs.	212	Headache	A. Aerogenes Eberthella Dubia Staph. Albus	B. Pyocyaneus Staph. Albus	B. Pyocyaneus Staph. Albus	21.5	0.4	24.5	0.5
2. Sn. Ureth. Cath.	- - -	212	None	B. Proteus B. Pyocyaneus	B. Pyocyaneus	B. Proteus B. Pyocyaneus	21.6	0.5	21.6	0.5
3. Hic. Ureth. Cath.	- - -	212	None	E. Coli, B. Proteus Colon Intermediate (Aerogenic)	B. Proteus Colon Intermediate (Aerogenic)	B. Proteus Colon Intermediate B. Pyocyaneus	21.5	0.4	21.5	0.5
4. Co. Ureth. Cath. + Fistula Lt. Renal Calculi Temp 102°F	- - -	212	None	A. Aerogenes Staphylococcus (Temp 102°F)	Staphylococcus (Temp 102°F)	A. Aerogenes Colon Intermediate Staph. Aureus I. Communis	20.0	0.4	20.5	0.5
5. Ph. Ureth. Cath.	200,000 Units 1 M Repeated Q3 Hrs. Total 1,000,000 in 15 hrs	187	None	A. Aerogenes B. Proteus	A. Aerogenes few colonies	A. Aerogenes	26.0	1.0	24.0	11.5
6. Gcs. Ureth. Cath. Lt. Calculi Pyonephrosis	- - -	187	None	B. Proteus A. Aerogenes	Sterile	A. Aerogenes B. Pyocyaneus	44.5	3.2	52.0	6.0
7. Gcs. Ureth. Cath.	- - -	187	None	A. Aerogenes	Sterile	Colon Intermediate (Aerogenic)	42.0	12.0	44.5	6.0
8. Lor. Ureth. Cath. Epididymitis	- - -	187	None	A. Aerogenes Eberthella Dubia Staph. Aureus	A. Aerogenes Staph. Aureus	A. Aerogenes Staph. Aureus	30.5	2.6	32.0	9.6
9. Lux. Ureth. Cath. Ureth. Fistula	- - -	187	None	A. Aerogenes B. Pyocyaneus Eberthella Pyogenes	Sterile	A. Aerogenes B. Pyocyaneus	44.5	3.2	52.0	9.6
10. Hon. Ureth. Cath. + Fistula Lt. Renal Calculi	- - -	187	None	A. Aerogenes Colon Intermediate	Sterile	A. Aerogenes	15.5	1.6	18.7	12.3
11. Gor. Ureth. Cath.	- - -	187	None	A. Aerogenes E. Coli Eberthella Oedematis Staph. Aureus	A. Aerogenes Staph. Aureus	A. Aerogenes B. Pyocyaneus E. Coli	8.5	1.0	-	-
12. Hon. Ureth. Cath. + Fistula	- - -	187	None	A. Aerogenes Col. Intermediate	A. Aerogenes (Few Colonies)	A. Aerogenes	22.0	0.6	51.0	0.9
13. Gcs. Ureth. Cath. Calculus Pyonephrosis Temp 103°F	200,000 Units 1 M + 100,000 Q3 Hrs. Total - 1,000,000 in 24 hrs.	226	Headache	B. Proteus	Sterile temp 106°F	B. Proteus	55.6	8.8	42.0	2.0
14. Hal. Suprapubic Cystostomy Catheter	- - -	226	Headache	A. Aerogenes B. Proteus	Sterile	Sterile	29.6	-	42.0	-
15. Rom. Suprapubic Cystostomy GSH Ureth. with Fobule Plastic OP	- - -	220	None	A. Aerogenes B. Pyocyaneus B. Proteus Colon Intermediate	Sterile (Ureth. Inflamm. subsided)	Sterile (No Inflamm. of Urethra)	53.7	0.5	31.6	1.0
16. De. Ureth. Cath. Fistula	- - -	226	None	A. Aerogenes B. Proteus	Sterile	A. Aerogenes	34.0	8.0	51.0	6.0
17. Dol. Ureth. Cath. Fistula Rt. Orchiectomy	- - -	226	None	A. Aerogenes E. Coli Staph. Aureus	A. Aerogenes B. Proteus	B. Pyocyaneus E. Coli A. Aerogenes	27.0	1.0	29.0	2.0
18. Co. Suprapubic Cystostomy	- - -	226	None	E. Coli Colon Intermediate (Aerogenic)	Sterile	E. Coli Colon Intermediate fewer colonies	24.5	2.0	14.2	1.0
19. Ke. Ureth. Cath.	- - -	226	None	A. Aerogenes	A. Aerogenes fewer colonies	A. Aerogenes	29.5	2.7	24.5	1.5
20. Be. Ureth. Cath. Fistula	- - -	226	None	A. Aerogenes B. Proteus B. Pyocyaneus	A. Aerogenes E. Coli	A. Aerogenes E. Coli	29.5	12.0	21.5	2.0
21. Le. Suprapubic Cystostomy	- - -	226	None	A. Aerogenes	Sterile	Aerogenes	43.0	14.2	45.0	8.9
22. Co. Ureth. Cath.	Local Streptomycin as Tidal Drainage 800 cc. 11 Saline Soln.	None	None	A. Aerogenes B. Streptococcus	A. Aerogenes E. Coli	A. Aerogenes Colon Intermed.				
23. Ph. Ureth. Cath.	- - -	None	None	A. Aerogenes	A. Aerogenes fewer colonies	A. Aerogenes				
24. Suu. Ureth. Cath.	Local Streptomycin as Tidal Drainage 600 U. 1 cc 11 H. Saline Soln.	None	None	A. Aerogenes	A. Aerogenes fewer colonies	A. Aerogenes				
25. Hin. Ureth. Cath.	- - -	None	None	A. Aerogenes	A. Aerogenes fewer colonies	A. Aerogenes				

Table III.—Table of 25 cases.

STREPTOMYCIN IN URINARY INFECTIONS

At first, the only available means of controlling urinary infections were penicillin and sulfonamides. We were reluctant to use sulfonamides since paraplegic patients developed anorexia from their use. Penicillin was used extensively and cleared the urines of staphylococci and streptococci, leaving the gram-negative bacilli unaffected.

Streptomycin in Paraplegia with Catheter

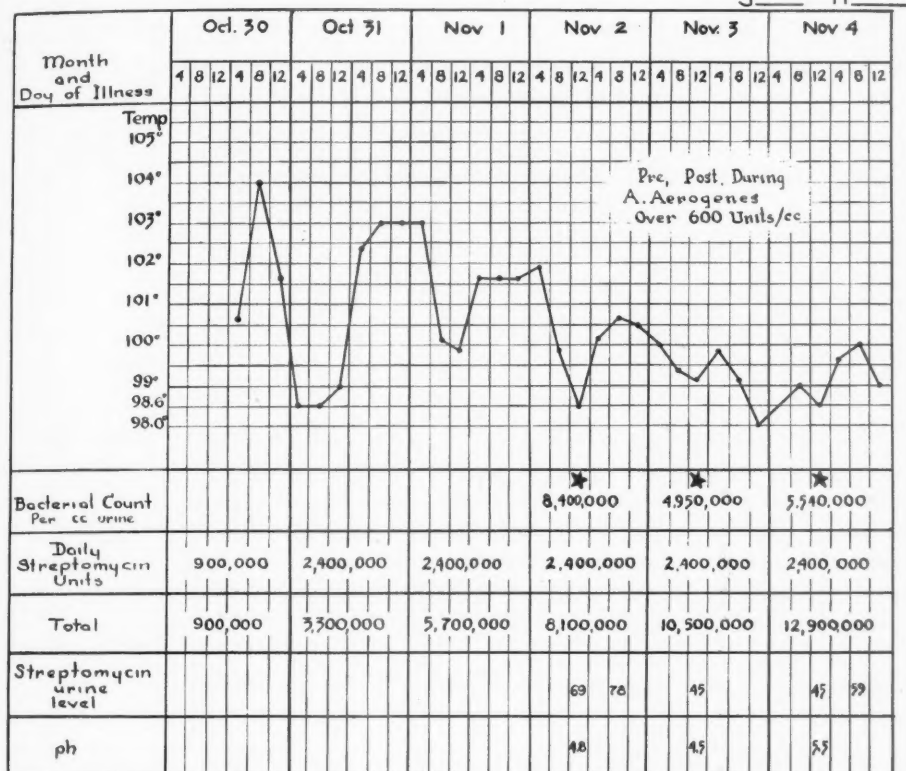


CHART I.—Cervical cord injury (C 7, partial), urethral catheter and pyelonephritis.
(cont'd on Chart II)

A new antibiotic, Streptomycin, was obtained in April, 1945. From the work of Schatz, Bugie and Waksman, and Robinson, Smith and Graessle it was known to inhibit gram-negative bacilli.*

Preliminary, *in vitro* studies in the laboratory demonstrated that *A. aerogenes*, *B. proteus* and *B. pyocyaneus* were inhibited by 25 units of Streptomycin per cc. in an F.D.A. broth culture.

* Streptomycin first was furnished by Merck & Company, Rahway, New Jersey. Appreciation is extended to their staff for many helpful suggestions and materials contributed.

When Streptomycin was given to patients intramuscularly in doses of 200,000 units every three hours, it was found by biologic assay that urine levels of 15 to 50 units could be attained at the end of three hours (Table II).

A series of 13 patients with no catheters but having infected neurogenic bladders were given a course of 1,000,000 units of Streptomycin each. After start of treatment at the end of six to nine hours urine cultures were found to be sterile; however, all but one developed reinfection with gram-negative bacilli within four to seven days after the treatment had been discontinued.

Streptomycin in Paraplegia with Catheter

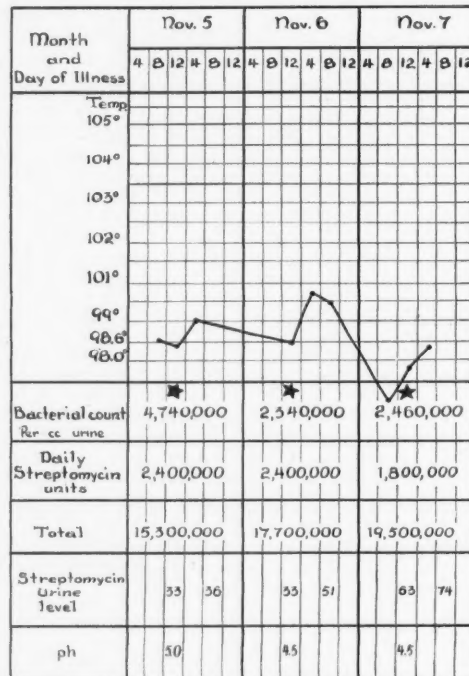


CHART II.—(continuation of Chart I).

When Streptomycin was first used in an attempt to control urinary infection in 26 paraplegic patients with indwelling catheters, the urines in ten of them became sterile at the end of 24 hours. However, in four to ten days after the treatment was stopped all became reinfected. Obviously, the catheter was the portal of infection. Local irrigation was tried in four cases using Streptomycin solution containing 160 to 600 units per cc. The cultures remained positive (Table III).

As more Streptomycin became available it could be used for prolonged periods and in larger doses. Paraplegic patients were given 300,000 units intramuscularly every three hours, until levels up to 70 to 100 units per cc. in

STREPTOMYCIN IN URINARY INFECTIONS

the urine could be obtained. At this time, it became apparent that gram-negative bacilli already exposed to Streptomycin developed strains resistant to it, or became Streptomycin-fast. Patients with *A. aerogenes* and *B. proteus* infections which could be cleared up by 25 units or less per cc. in April, by June, developed strains of these bacteria which were resistant to 600 to 700, and some

Streptomycin in Paraplegia with Catheter

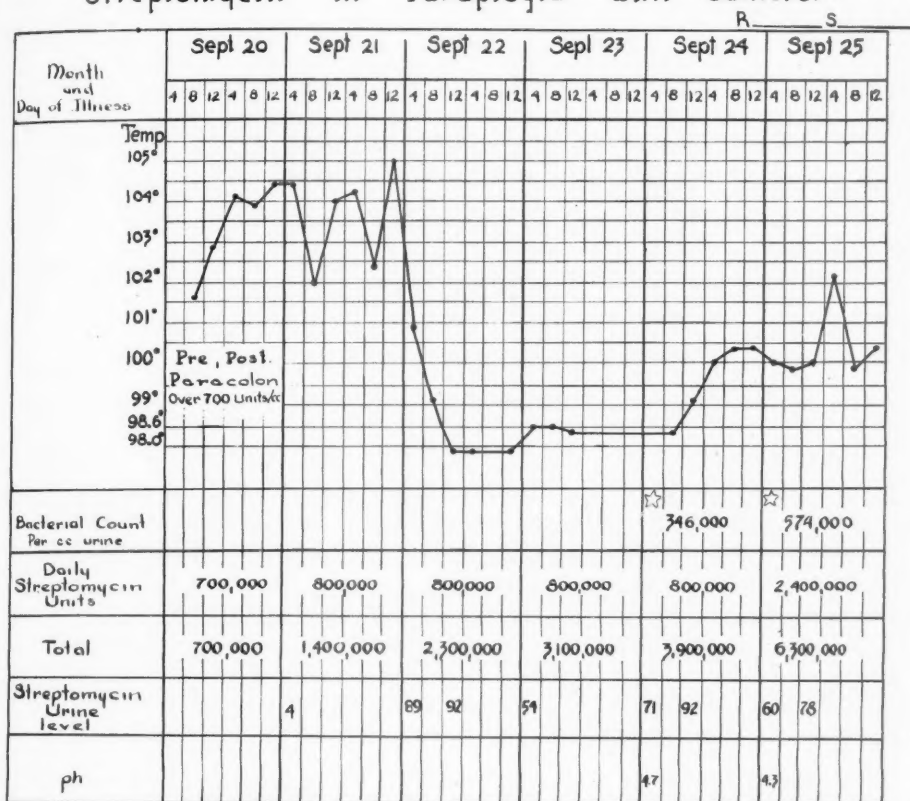


CHART III.—Complete cord transection at D 8, urethral catheter and pyelonephritis (cont'd on Chart IV)

to over 1,000 units per cc. As it is not feasible to obtain such high concentration of Streptomycin in the urine it would be impossible to destroy these bacteria completely. However, clinically, the patient improved when Streptomycin was given, temperatures were lowered more rapidly than before and colony counts in urine cultures definitely diminished. Fluid intake of these patients was kept at 3,000 cc. per 24 hours. Thus, Streptomycin was used routinely on all paraplegics who showed signs of increasing urinary infection, such as elevated temperatures, chills, increasingly cloudy urine and toxemia. It definitely reduced unpleasant complications.

Streptomycin in Paraplegia with Catheter

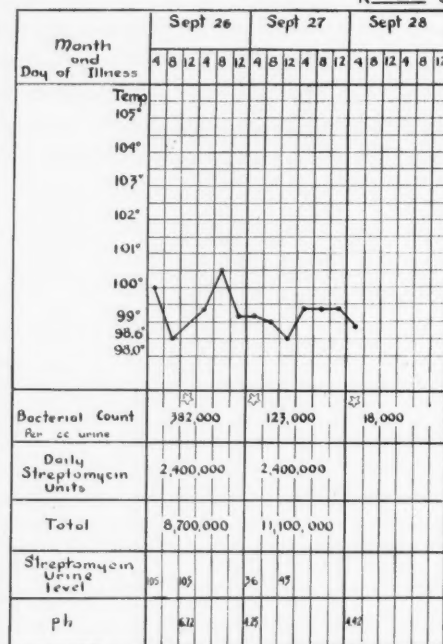


CHART IV.—(continuation of Chart III)

Streptomycin in Paraplegia with Catheter

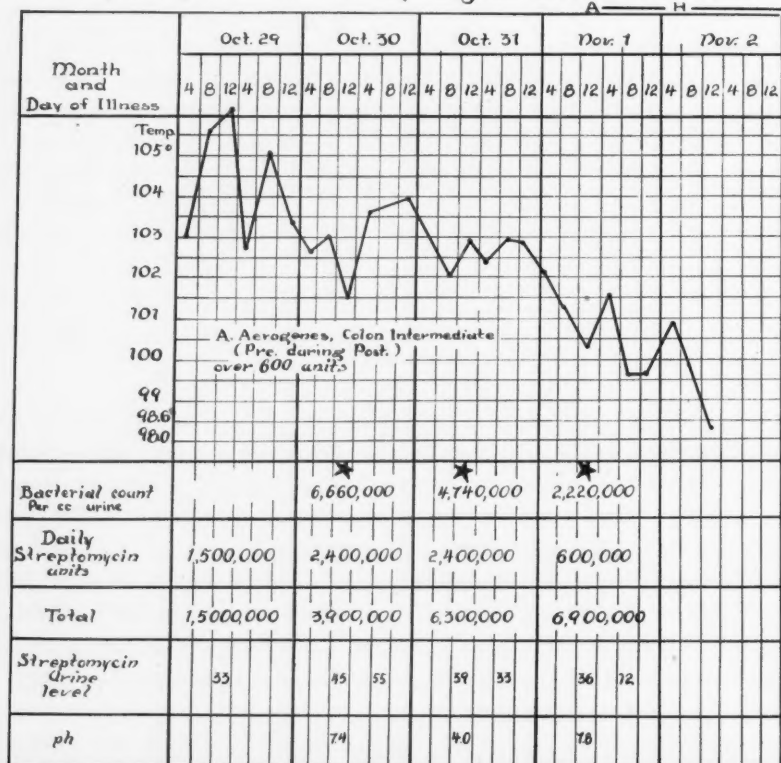


CHART V.—Cervical cord injury (C 7, partial) with urethral catheter and pyelonephritis.

STREPTOMYCIN IN URINARY INFECTIONS

Streptomycin in Paraplegia with Catheter

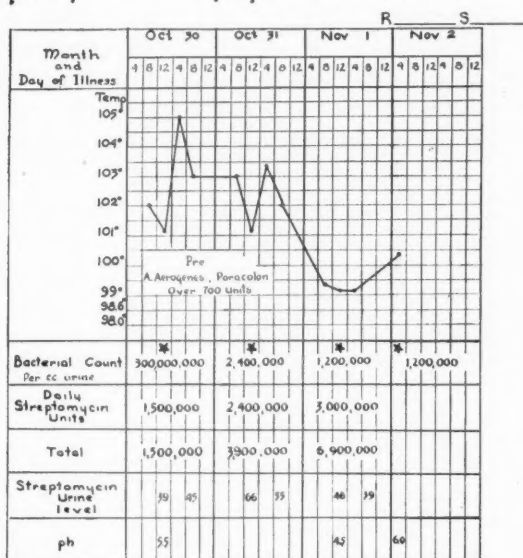


CHART VI.—Complete cord transection at D11, with urethral catheter and pyelonephritis (cont'd on Chart VII).

Streptomycin in Paraplegia with Catheter R-S-

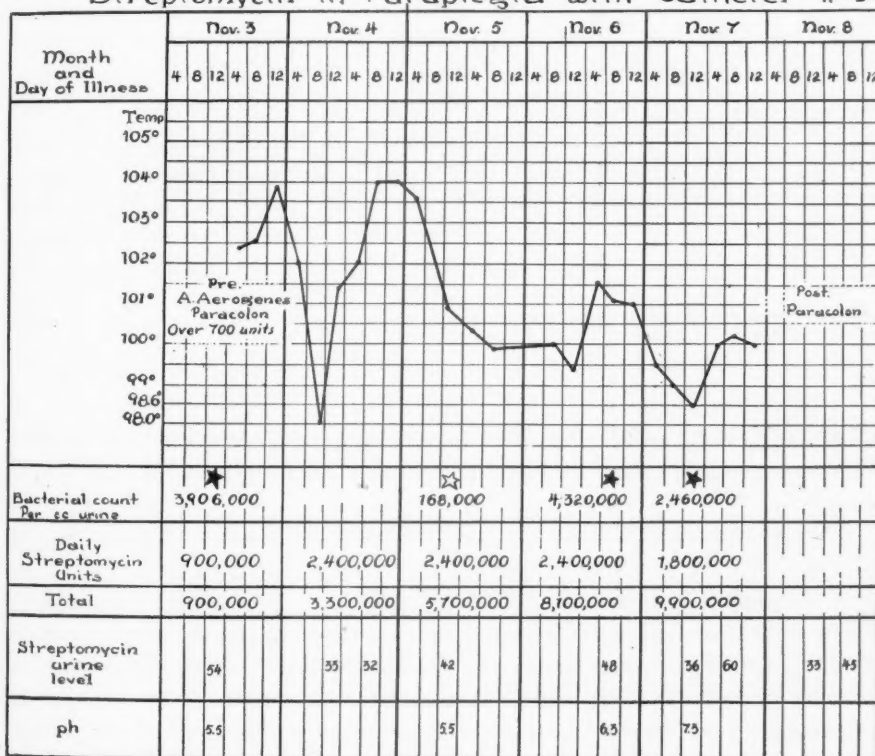


CHART VII.—(continuation of Chart VI)

It was noted in the laboratory that the colony morphology of the gram-negative bacilli changed after patient had been treated with Streptomycin. *A. aerogenes* colonies became flat, rough and dry instead of being mucoid. *B. proteus* began to grow in isolated colonies instead of spreading and overgrowing the plate. This would confirm the observations of Robinson, Smith and Graessle, based on experiments carried on *in vitro*, to the effect that the

Streptomycin in Paraplegia with Catheter

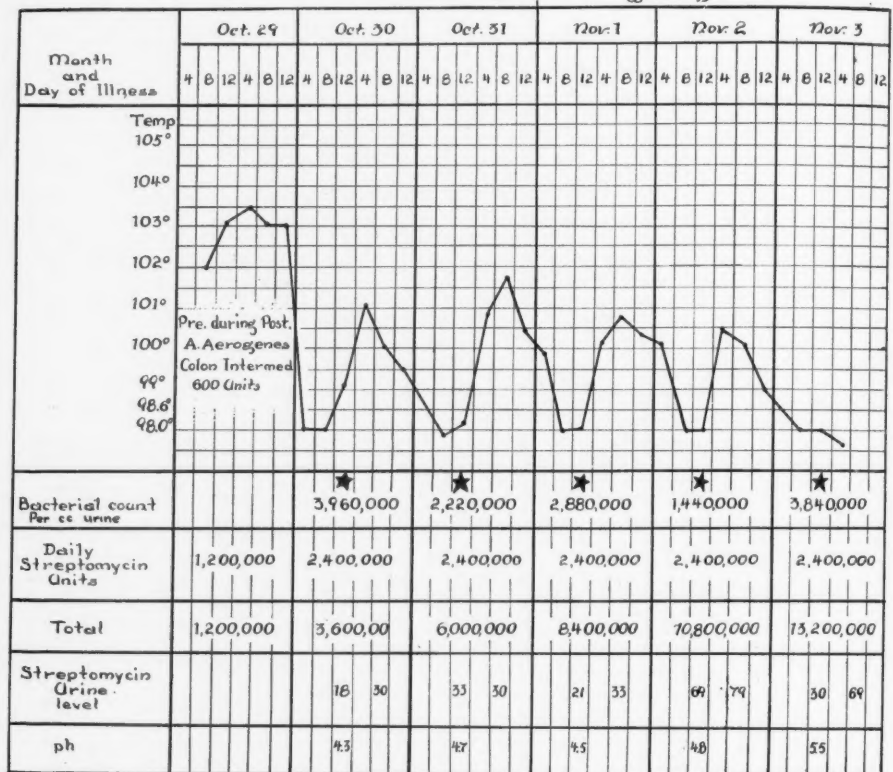


CHART VIII.—Complete cord transection at D10, with urethral catheter and pyelonephritis.

pathogenicity may be reduced and morphologic changes occur with resulting decrease in multiplication of bacteria even if the bacteria are not completely destroyed.

Charts of patients' reaction to Streptomycin are shown, indicating the colony count per cc. of urine decreased as temperature drops. Toxic reactions from Streptomycin were slight; 20 per cent of patients receiving it complained of frontal headaches, joint pains and malaise. Two per cent had a temperature rise up to 101° F. These toxic effects were ascribed to histamine-like constituents in certain batches of Streptomycin and have decreased as methods of manufacture have improved. Liver and kidney function tests on all patients

before and after treatment showed that no impairment followed use of Streptomycin (Chart II-VIII).

Urinary calculi and abscesses of kidney and lower urinary tract cannot be expected to respond to Streptomycin given parenterally, unless treated surgically first. Local irrigation of renal pelvis in the presence of obstructing calculi and local irrigations of testicular abscesses with Streptomycin solution 5,000 units per cc. (high concentration necessary because of increasing bacterial resistance to Streptomycin), were of limited value in affecting the bacteria, although, clinically, these treatments seemed to reduce the virulence of infection. No objective evidence can be proffered at present that resistant gram-negative bacilli are rendered less pathogenic by Streptomycin, but with more laboratory work it may be found that diminution in their motility, loss of their capsule, as well as reduction in their urea-splitting, stone-forming faculties do occur. Streptomycin is probably the only specific antibiotic at present which will control these intractable gram-negative bacillary infections of the urinary tract, so common in patients with incompetent internal sphincters and indwelling catheters. Since almost identical bacterial flora is found in stool cultures of paraplegic patients, as in their urine the question of cross-infection between individuals on a ward must be considered, as well as possibility of direct invasion of colon bacteria into the paralyzed urinary tract. Constant vigilance on the part of the urologist is necessary to prevent overwhelming infiltration of gram-negative bacilli into this susceptible medium.

Streptomycin has been proven to be a valuable antibiotic aid in controlling heretofore intractable urinary infections. However, the principles of sound urologic and surgical practice still apply. These are: good drainage without residual urine; elimination of mechanical obstruction; and clearing of foci of infection and removal of avenues of infection, such as the catheter. So long as paraplegic patients possess incompetent sphincters they will have urinary complications. These infections are controlled by antibiotics, such as Streptomycin, but they are not eradicated.

SUMMARY

1. Streptomycin was used in 13 cases of neurogenic bladders voiding without catheters—nine became sterile but were reinfected in four days.
2. Streptomycin was used in 22 cases of neurogenic bladders with catheters indwelling, ten became sterile in 24 to 48 hours, two remaining sterile for four days, but all had a recurrence of infection.
3. Local irrigation with Streptomycin solution has a limited value.
4. Gram-negative bacilli became resistant to Streptomycin once exposed to it and not completely destroyed.
5. Clinical improvement and lowered colony counts were noted in urine cultures of paralyzed patients infected with Streptomycin-resistant bacteria, when larger doses of Streptomycin were given.
6. Morphologic changes have been noted in gram-negative bacilli exposed to Streptomycin.

CONCLUSIONS

Streptomycin is an important new antibiotic useful in controlling gram-negative bacilli infecting the urinary tracts of paraplegic patients. Therapy should be based on sensitivity of the organisms to the antibiotic, and dosage and length of administration adjusted according to severity of infection, large initial doses being the most efficacious.

Appreciation is extended to Miss C. Gunn, Miss M. Meyer and Miss M. Reilly for the help they have given in the laboratory.

Acknowledgment is made to Col. E. L. Cook, Commanding Officer of Newton D. Baker General Hospital for his interest and to Col. D. H. Poer, Chief of Surgical Service, for his kind suggestions and aid in preparing this report.

REFERENCES

- Chemotherapeutic Properties of Streptomycin. Harry J. Robinson, Dorothy G. Smith and Otto E. Graessle. (Introduced by H. Molitor.) Proceedings of the Society for Experimental Biology and Medicine, Volume 57, Number 2, November, 1944, Page 226.
- Schatz, A., Bugie, E., and Waksman, S. A.: Proc. Soc. Exp. Biol. and Med. 1944, 55, 66.
- A Method for Determination of Streptomycin in Body Fluids by Robert J. Stebbins and Harry J. Robinson.
- Proc. of the Society for Exp. Biol. and Med., June, 1945, Vol. 59, Number 2, Page 225.

A NEW METHOD FOR CONSTRUCTING AN ARTIFICIAL ESOPHAGUS*

WILLIAM P. LONGMIRE, JR., M.D., AND MARK M. RAVITCH, M.D.

BALTIMORE, MD.

FROM THE DEPARTMENT OF SURGERY OF THE JOHNS HOPKINS UNIVERSITY AND
THE JOHNS HOPKINS HOSPITAL, BALTIMORE, MD.

THE PURPOSE of this communication is to report a new method for constructing an artificial antethoracic esophagus. A loop of jejunum which is ultimately completely isolated from its mesenteric blood supply is implanted in a skin tube and is transferred to the anterior chest wall in order that it may serve as a channel between the upper part of the esophagus and the stomach.

In all of the numerous previously devised methods for transferring various segments of the alimentary tract to the anterior chest wall, the mesenteric blood supply has been retained. The use of a segment of intestine as a free graft has apparently not been previously described.

In the surgical treatment of malignant esophageal lesions there is a growing tendency to reestablish the continuity of the alimentary tract at the time of the excision of the original lesion by mobilization of all or a part of the stomach or jejunum. The reports of Garlock,¹ Sweet,² Clark,³ and others, indicate that such primary anastomoses may be successfully performed for lesions as high as the arch of the aorta. If wide excision of the growth is not hampered, and if the operative mortality is not excessive, such one-stage procedures are certainly to be preferred to the older Torek operation. There are, however, still numerous cases in which, because of the location or extent of the growth, the poor general condition of the patient, or unfavorable results from mobilization of the stomach or jejunum, it is necessary to exteriorize the oral end of the esophagus and to perform some type of delayed esophageal reconstruction. The impermeable benign strictures of the esophagus, unless they are so localized that resection and primary anastomosis may be feasible, are at present probably best treated by some type of antethoracic reconstruction. Delayed esophageal reconstruction may also be indicated in cases of congenital atresia when a primary anastomosis cannot be performed.

The technic described in this paper was first proved to be feasible in a series of experimental animals, and it has subsequently been used on three patients. In one patient the procedure has been completed. A brief review of these cases will be given after the experiments have been described.

In the past, interest in isolated intestinal segments has chiefly been confined to the study of the physiology of the alimentary tract and its reaction to various drugs. Puestow,⁴ in 1932, exteriorized various segments of the small intestine and partially embedded them in an abdominal incision. At a later date these segments were separated from all their mesenteric attachments. After division

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

of the entire mesentery the peristaltic response to eating was less than normal. This he attributed to division of the mesenteric nerves. In 1939, Reagan and Puestow⁵ prepared similar isolated segments of the colon and found that their response to various drugs was unchanged by division of the mesenteric vessels and nerves.

In 1942, Davis and Stafford⁶ reported a case from the Surgical Service of the Johns Hopkins Hospital in which, using Lexer's method, they had successfully constructed an antethoracic esophagus. The ultimate fate of the blood supply of the transplanted jejunal segment aroused their interest.

EXPERIMENTAL OBSERVATIONS

Shortly after the completion of this reconstruction by Davis and Stafford, Doctor Stafford began a series of experiments on dogs which were designed to determine whether small segments of the intestinal tract would survive as free grafts, isolated from the mesenteric blood supply, when transplanted into the subcutaneous tissue of the abdominal wall. During Doctor Stafford's absence with the 18th General Hospital the experiments were completed by us, and they are included in this report with his permission.

SERIES 1.—Four dogs were used. A single primary mesenteric artery and vein of the upper jejunum were isolated and a small segment of intestine supplied by these vessels was resected. The resected segment was placed in a subcutaneous tunnel with the mesenteric artery and vein passing through the abdominal wall. The ends of the intestine were brought to the outside through stab wounds in the skin. One of these animals died of distemper several months after operation. Nine months after operation the remaining three dogs were explored and the mesenteric vessels divided. All the intestinal grafts survived and showed no ill effects from the procedure (Fig. 1).

It then occurred to one of us (M. M. R.) that a longer segment of intestine might be isolated, enclosed in a skin tube, and transplanted into any desired position, and that it might be possible to construct a complete antethoracic esophagus from such a jejunal graft.

SERIES 2.—In the second series of experimental animals nine such intestinal-skin tubes were prepared in the following manner: A right rectus incision was made and the upper jejunum was identified. In this region the primary intestinal arteries anastomose through a single arcade which lies close to the mesenteric border of the jejunum. The terminal arteries arise from the arcade and pass directly to the intestine. By careful selection a segment of jejunum 15 to 20 cm. in length can be found which will be nourished by a single primary intestinal artery and vein. After selecting such a vessel and segment of jejunum, we isolated the intestine and freed the vessels from the mesentery. The continuity of the intestinal tract was restored. A skin tube of sufficient length and width was undermined adjacent to the original incision. A stab wound was made through the musculature of the abdominal wall beneath the central portion of the skin tube and the jejunal loop delivered through this wound. The peritoneum and musculature of the original incision were closed.

ARTIFICIAL ESOPHAGUS

The intestine was enclosed in the skin tube with a central pedicle about the intact mesenteric vessels. The ends of the jejunal graft were brought out through stab wounds at either end of the skin tube.

FIG. 1

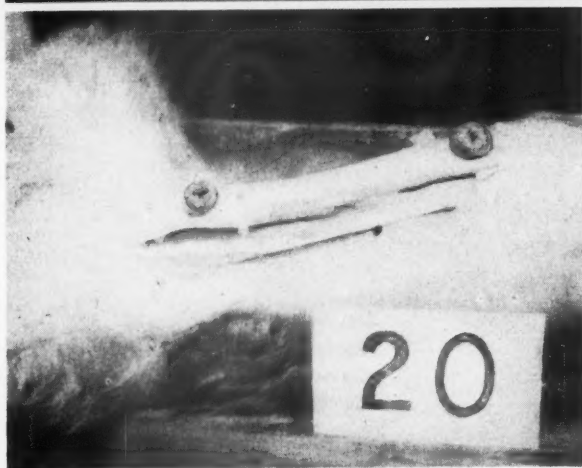
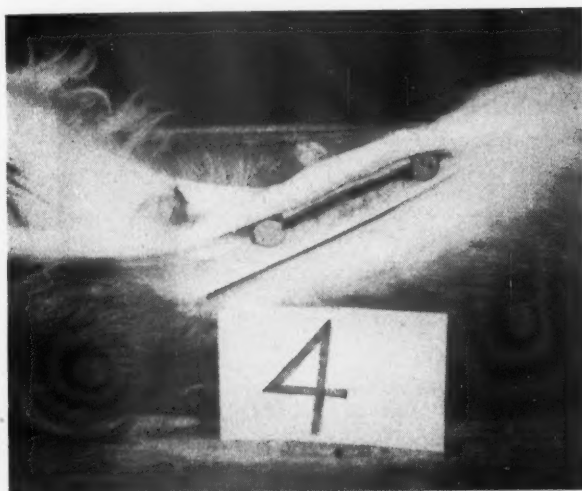


FIG. 2

FIG. 1.—Dog. No. 4, with short segment of jejunum enclosed in skin tube. Mesenteric vessels completely divided.

FIG. 2.—Dog No. 20. Long segment of jejunum enclosed in skin tube with intact mesenteric vessels passing through central pedicle.

In five of the nine dogs the results were considered good. The entire jejunal loop survived, and the skin tube healed satisfactorily (Fig. 2). The results were fair in two dogs. The skin tube healed satisfactorily but there was loss of a part of the jejunal loop. In two dogs the jejunal transplant became completely gangrenous. The most likely explanations were that the mesenteric ves-

sels had been twisted at the time the loop was brought out through the stab wound or that the central pedicle was made too small and the vessels had been constricted.

In the six experiments in which the loop remained viable, six weeks later the central pedicle was clamped with a rubber-shod clamp for progressively longer periods of time in order to hasten the establishment of collateral circulation. When the collateral circulation seemed adequate, the central pedicle was divided and the mesenteric vessels were ligated (Fig. 3). Division of the



FIG. 3.—Dog No. 20, with mesenteric vessels and central pedicle divided.

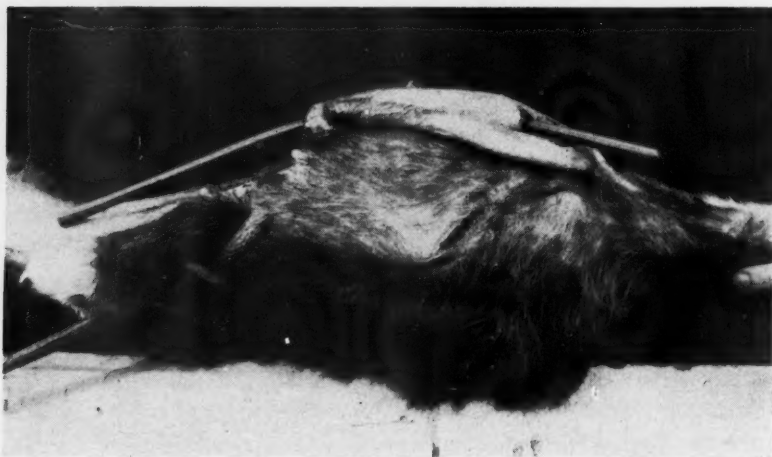


FIG. 4.—Dog No. 20, with intestinal-skin tube transplanted to anterior thorax. Catheter inserted into intestinal segment.

mesenteric vessels in four of the dogs had no permanent effect on the jejunum or the skin tube. One tube in which there was partial loss of jejunum following the first stage showed further loss of the intestine after the second operation, leaving only about one half of the original jejunal loop. In the remaining experiment, in which partial loss of the jejunum occurred after the first stage, the entire segment disappeared after the mesenteric vessels had been divided.

ARTIFICIAL ESOPHAGUS

One week later, after satisfactory tests with intermittent occlusion, the lower pedicle was divided. The caudal end of the intestinal-skin tube was rotated to the upper thoracic region, opened and implanted (Fig. 4). This procedure was carried out on four dogs. Two of the transplanted intestinal-skin tubes healed *per primam*. Infection beneath the tube in the other two dogs caused partial loss of the graft.

In one dog in which a satisfactory intestinal-skin tube had been rotated to the anterior chest wall an attempt was made to anastomose the proximal end of the esophagus and the stomach to the transplanted intestine. This animal died on the fifth postoperative day of an extensive gas infection of the cervical region following leakage from the upper anastomosis. Further attempts to complete the procedure in other animals were not made because of inadequate personnel to care for the dogs during the postoperative course when intravenous fluids and other forms of treatment were necessary.

Four months after the mesenteric vessels had been divided the isolated jejunal grafts showed evidence of moderate atrophy of the musculature but were otherwise grossly normal. The mucosa appeared normal and continued to secrete small amounts of mucoid material. Peristaltic movements were frequently seen, arising both spontaneously and from mechanical stimulation such as pinching or distending the intestine. On microscopic examination the normal architecture of the intestine was seen to be preserved.

These experiments demonstrated for the first time that a long segment of the jejunum, when placed within a skin tube, develops sufficient collateral circulation to allow division of the mesenteric vessels, and that by means of such an intestinal-skin tube, free jejunal grafts might be transferred from the abdomen to the chest and neck.

CLINICAL AND OPERATIVE PROCEDURE

From the experience gained in the experimental work on animals, we were encouraged to attempt the method on patients. The technic used clinically by one of us (W. P. L., Jr.) has varied from the experimental procedure only in detail; the principles are the same. The major difference has been that the entire procedure has been divided into more stages.

There are five principal steps in the procedure. Certain of these, however, may necessitate multiple stages and variations depending upon the conditions that are met. Familiarity with the technic of the formation and transfer of skin tubes is essential before undertaking the procedure.

STEP I.—The level of the esophageal stricture is carefully determined by roentgenologic and esophagoscopy examination, and the distance from the cervical region above the stricture to a point below the costal margin is measured. The isolated intestinal loop is made somewhat longer to allow for shrinkage during transfer. The future position of the isolated loop when transplanted into the subcutaneous tissue of the left thoraco-abdominal region is determined, and the outline of the proposed skin tube that will eventually enclose the intestine is marked with brilliant green. This outline is made before the first stage

is carried out so that the original left upper rectus incision may be made through the skin and subcutaneous tissue in line with the medial edge of the proposed skin tube (Fig. 5 A).

The abdomen is opened through this incision and the first portion of jejunum is identified. The vascular pattern of the mesentery is inspected and a segment of jejunum of the desired length is selected. To obtain a sufficient length of jejunum in the human being it is necessary to select one primary

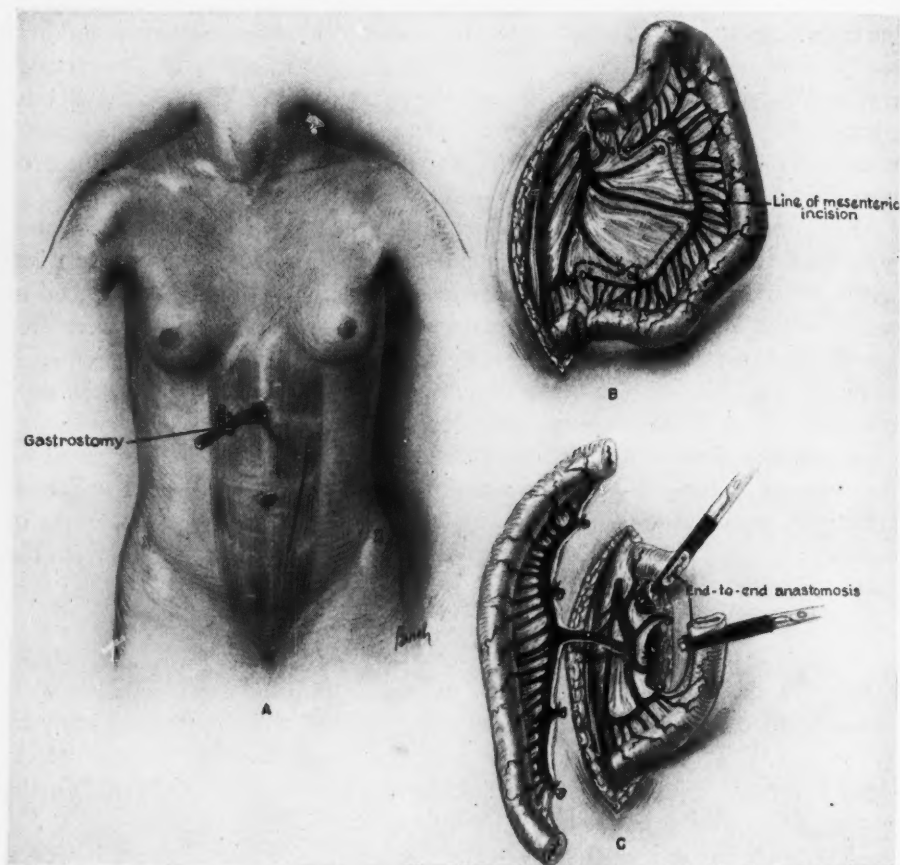


FIG. 5.—(A) Location of original left rectus incision.

(B) Line of division of intestine and mesentery.

(C) Jejunal segment isolated with single mesenteric artery intact. Mesenteric veins not shown.

mesenteric artery and vein which are to remain intact and to divide a similar set of vessels on either side of this point (Fig. 5 B). The arcuate vessels do not lie as near the mesenteric border of the jejunum in the human being as they do in the dog, and thus the isolated segment with its vascular supply is bulkier in the human being. The segment is cut from the jejunum and the continuity of the intestinal tract is restored by anastomosing the two ends. The isolated loop is now attached by a single primary mesenteric artery and vein (Fig. 5 C).

ARTIFICIAL ESOPHAGUS

The skin and subcutaneous tissue of the lateral border of the incision are elevated from the musculature and a subcutaneous tunnel dissected above and below the area beneath the proposed skin tube. A stab wound is made through the musculature and peritoneum beneath the mid portion of the skin tube, and the isolated jejunum is delivered through this incision. The jejunal segment is now implanted in the subcutaneous tunnel and the ends are brought to the outside by means of stab wounds through the skin at the limits of the tunnel.* The mesenteric artery and vein are left intact

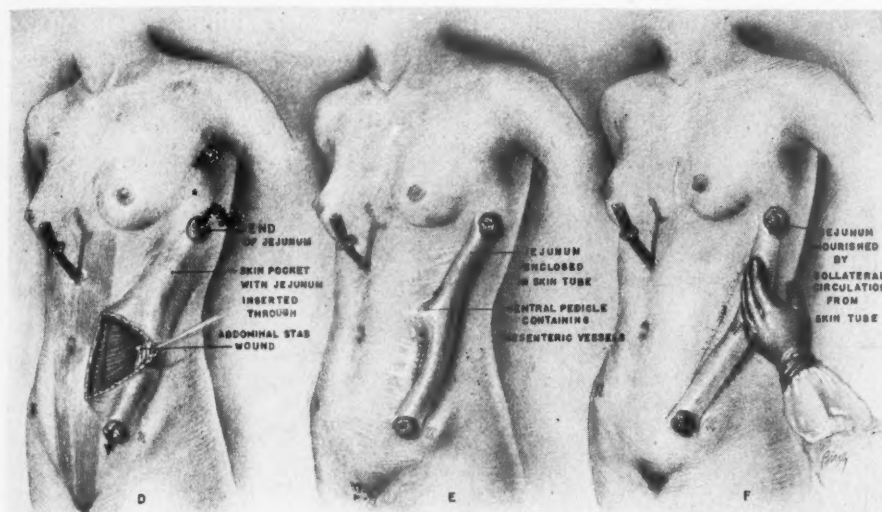


FIG. 6.—(D) Isolated intestine implanted in subcutaneous tunnel with mesenteric artery and vein passing through stab wound.
(E) Central pedicle skin tube formed about isolated intestine.
(F) Central pedicle and mesenteric vessels divided.

and pass through the first stab wound in the abdominal wall (Fig. 6-D). The original left rectus incision is closed. A period of at least a month is allowed to elapse for all edema and reaction about the implanted jejunum to subside before the second stage is carried out.

STEP 2.—The usual technic for the construction of a central pedicle skin tube has been employed (Fig. 6 E). In two of the cases to be reported only one-half of the tube was formed at a time. It is necessary to make a wide skin tube in order to be able to enclose the intestinal loop. The formation of the intestinal-skin tube is greatly facilitated if the diet of the patient is controlled and the amount of subcutaneous fat is kept at a minimum.

On two occasions it has been necessary to cover a part of the under surface of the tube itself with a split-thickness graft as it was not possible to obtain a wide enough tube to encircle the intestine properly. The use of such grafts on

* In a recent case a segment of the central portion of the loop was resected as the intestinal loop is redundant when it is straightened. This procedure does not shorten the length of the loop as the length is actually determined by the mesenteric vessels rather than by the intestine itself.

the tube, however, is not recommended as it reduces the area through which collateral circulation is carried to the intestine when the mesenteric vessels are divided.

STEP 3.—Before completely dividing the central pedicle including the mesenteric vessels it is usually necessary to narrow the pedicle by further division of part of the surrounding skin. A rubber-shod intestinal clamp or a rubber band is used for temporary occlusion of the mesenteric vessels to aid in the development of collateral circulation. Temporary occlusion is continued several times a day for at least a week or until there is no change in the circulation of the skin tube after occlusion of the pedicle for 15 minutes. The mucosa of the jejunum is very sensitive to circulatory changes and will become moder-

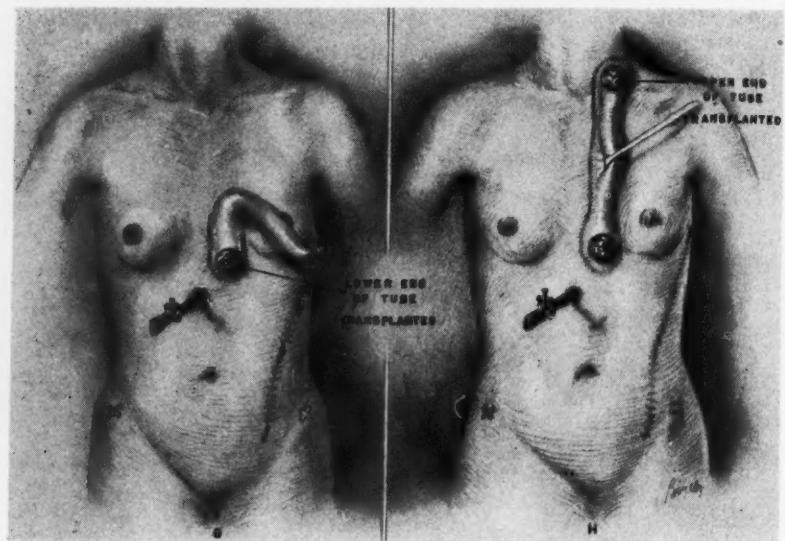


FIG. 7.—(G) Lower portion of intestinal-skin tube transplanted to left upper abdominal and lower thoracic region.
(H) Upper pedicle divided. Entire tube opened and implanted over left anterior chest.

ately cyanotic even after there is sufficient collateral circulation for the ultimate survival of the jejunum. After sufficient collateral circulation has developed the central pedicle is divided, the mesenteric vessels are ligated, and the defects on the tube and the abdominal wall are closed (Fig. 6 F). A month is then allowed for the disturbed circulation to become readjusted.

STEP 4.—The lower pedicle of the intestinal-skin tube is now temporarily occluded several times a day until circulation from the upper pedicle is sufficient to support the entire tube; it is then divided, usually in three stages, and transferred to the upper left abdominal region (Fig. 7 G). Care is used to implant the lower end of the tube high enough so that there will be adequate jejunum to reach easily to the cervical region when the upper portion of the tube is transferred. About one quarter of the lower end of the tube is implanted in the upper abdomen and chest wall in order to establish a wide pedicle to carry collateral circulation. A month or so later the upper pedicle is divided

ARTIFICIAL ESOPHAGUS

and the entire tube is opened and implanted along the anterior chest wall. The upper end of the tube is placed along the anterior border of the left sternocleidomastoid muscle (Fig. 7 H).

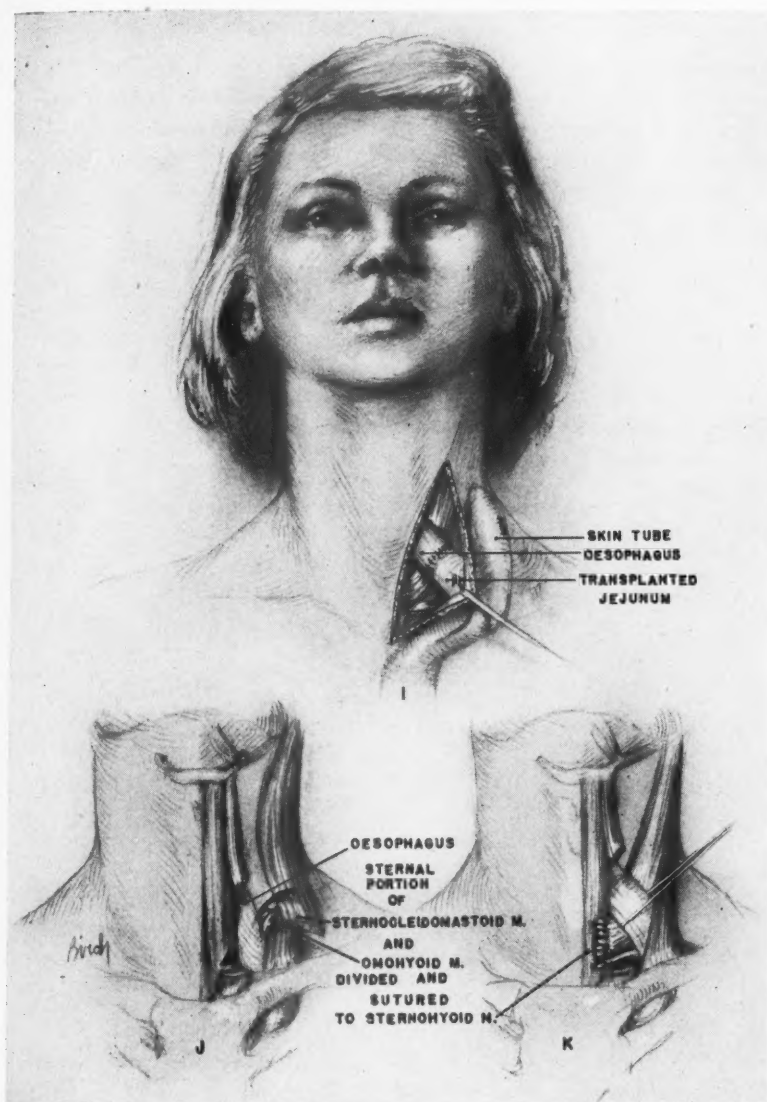


FIG. 8.—(I) End-to-side anastomosis between transplanted jejunum and mobilized cervical esophagus.

(J) and (K) Sternal portion of sternocleidomastoid muscle and omohyoid muscle passed beneath mobilized cervical esophagus and sutured to sternohyoid muscle.

STEP 5.—If the thoracic portion of the esophagus has not been removed as in the case of a benign stricture or congenital atresia, some type of lateral anastomosis should be performed in preference to dividing the esophagus and leaving a blind segment within the mediastinum. In one case reported in this

paper the end of the transplanted jejunum was anastomosed to the side of the cervical esophagus. Before the anastomosis was performed the cervical esophagus was explored and dissected from its usual position. The sternal portion of the sternocleidomastoid muscle and the omohyoid muscle were divided, passed beneath the esophagus, and sutured to the sternohyoid muscle. This maneuver held the esophagus in the superficial tissues and relieved tension on the suture line when the anastomosis was performed (Figs. 8 J and K). The area was packed with iodoform gauze so that the region became sealed off from the cervical and mediastinal spaces. One week later the incision was reopened and the end of the jejunal transplant anastomosed to the side of the esophagus (Fig. 8 I).

The lower end of the jejunal transplant has been anastomosed to the stomach in two patients. In the first there was sufficient length of the graft

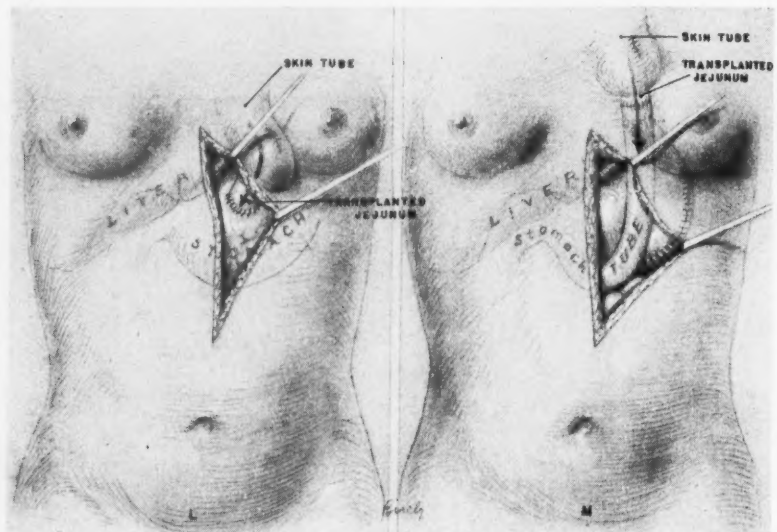


FIG. 9.—(L) End-to-side anastomosis between lower end of transplanted jejunum and side of stomach.

(M) Gastric tube formed from greater curvature and brought up anterior to costal margin for end-to-end anastomosis with lower end of transplanted jejunum.

below the costal margin to bring the end of the jejunum through a small upper left rectus incision and anastomose it directly into the side of the stomach.

In the second patient the lower portion of the graft was lost. After transplantation the graft extended from the cervical region down to the fifth interspace. A tube similar to the Beck-Jianu gastrostomy tube was formed from the greater curvature of the stomach and this was brought up over the costal margin and anastomosed to the lower end of the jejunal graft (Fig. 9 M).

A more detailed report of the clinical use of this method follows.

CASE REPORTS

Case 1.—The patient, E. R., was a 36-year-old white woman who had swallowed "several mouthfuls" of a caustic alkaline hair bleach in September, 1942. During the

ARTIFICIAL ESOPHAGUS

following 20 months she had received fairly regular esophageal dilatations at weekly intervals. In spite of this treatment the scarred areas became denser and the patient had increasing difficulty in taking adequate nourishment. Roentgenography showed diffuse irregular constriction of the middle third of the esophagus with almost complete obstruction. The esophageal stenosis became so severe that gastrostomy was performed in January, 1944, and retrograde dilatations were attempted without success. Finally, in May it was decided to attempt the formation of an artificial antethoracic esophagus following the general outline of the method just described.

On May 18, 1944, a suitable segment of the upper jejunum was transplanted into the subcutaneous tissue. One month later the jejunal loop was enclosed in a skin tube with a central pedicle about the mesenteric vessels. As insufficient skin was obtained for complete encirclement of the lower third of the intestine, a split-thickness graft was used to complete the under surface of this portion of the tube. The tube was sufficiently long to allow the lower pedicle to be divided and implanted just below the left costal margin before the central pedicle was severed. This transfer was performed on August 3. On September 11 the central pedicle and the mesenteric vessels were divided and the lower one-fourth of the tube was implanted along the left border of the sternum.

After division of the mesenteric vessels the lower third of the jejunal tube that had been partially covered with a split-thickness graft failed to develop an adequate collateral circulation and sloughed. This mishap delayed the next procedure until December 23, when the upper pedicle was completely divided, brought up to a point one inch above the clavicle, and implanted along the left border of the sternum.

On February 5, 1945, the cervical esophagus was mobilized and placed in the subcutaneous region according to the method previously described under Step 5 in the preceding section. One week later the end of the jejunal graft was sutured into the side of the mobilized cervical esophagus. A fistula developed at the site of this anastomosis but closed spontaneously in three weeks (Fig. 10). The patient now had a satisfactory antethoracic esophagus lined with mucous membrane down to the level of the fifth costal cartilage, just above the costal margin; but owing to the loss of the lower third of the jejunal graft, an additional procedure was necessary to complete the channel into the stomach. On March 29 a Beck-Jianu gastric tube was formed from the greater curvature of the stomach and anastomosed to the lower end of the jejunal graft (Fig. 9 M). A fistula developed at this anastomosis, the closure of which required two subsequent operations.

There is still a moderate narrowing of the lumen at the gastrojejunal junction, but the patient now swallows liquids and soft foods. It is planned to dilate the area after healing is firm. When the patient swallows, the bolus of food passes rapidly through the oral segment of esophagus into the jejunal tube. The jejunum usually becomes moderately distended; then active peristaltic waves carry the contents into the gastric tube and on to the stomach. Occasionally reversed peristalsis causes a slight reflux into the esophagus and the patient has to swallow again. This reversal has never been great enough, however, to cause the patient to vomit or even to taste the regurgitated contents.

Case 2.—T. H., a white male infant with atresia of the esophagus and a tracheoesoph-



FIG. 10.—Photograph of patient E. R. after end-to-side anastomosis of transplanted jejunum to esophagus.

ageal fistula, was operated upon on September 8, 1942, when five days old, by Dr. Alfred Blalock. The blind oral end of the esophagus was exteriorized above the left clavicle and the abdominal portion of the esophagus delivered through an upper left rectus incision to serve as a gastrostomy.

On April 22, 1943, an unsuccessful one-stage attempt was made to form a skin-tube antethoracic esophagus of the Bircher type.

The present method was begun on October 28, 1943, when the child was 13 months old. In spite of the extremely poor condition of the infant and numerous unrelated complications such as osteomyelitis of the humerus, dislocation of the hip, otitis media, anal stenosis, and numerous attacks of diarrhea, a satisfactory intestinal-skin tube was formed, transferred to the anterior chest wall, and anastomosed to the stomach and esophagus (Figs. 11 to 15). A fistula developed at the site of the esophagojejunal anastomosis, and

before this was closed the patient died on July 2, 1945, of a pyocyaneus septicemia. All of the operative areas were healed at this time. At autopsy there was no evidence of infection about any portion of the transplanted intestinal skin tube.

Case 3.—R. C., a 25-year-old white woman with an impermeable stricture of the esophagus due to the ingestion of lye, now has a complete intestinal-skin tube and the mesenteric vessels have been divided. At present the tube is ready to be transferred to the anterior chest wall (Fig. 16).

DISCUSSION

Although primary anastomoses are being performed more frequently now than formerly after resections of malignant esophageal lesions and for congenital atresia, there are still numerous cases in which the oral end of the esophagus must be exteriorized and some form of secondary antethoracic construction carried out. Such esophageal reconstructions are also indicated in certain cases of benign impermeable strictures if dilatations have failed.

Although numerous types of antethoracic esophageal reconstruction have been devised, relatively few com-

FIG. 11.—Patient T. H. following first stage, with isolated jejunal loop implanted in subcutaneous tunnel.

pleted cases by any method have been reported. Most of the technics are laborious and uncertain. Some, such as the gastroesophagoplasty, have an excessive mortality rate (66.3 per cent).⁷

The jejunodermato-esophagoplasty of Lexer has been the most popular type of reconstruction but has the disadvantage of being formed largely of an inactive skin tube which, in certain persons, may contain enough hair to cause

ARTIFICIAL ESOPHAGUS



FIG. 12.—Lower half of central pedicle skin tube formed.



FIG. 13.—Completed intestinal-skin tube with intact central pedicle.



FIG. 14.—Lower pedicle divided and implanted in left upper quadrant. In this patient the mesenteric vessels and central pedicle were not divided until after this stage.

obstructive signs. The three anastomoses—the esophagus to the skin tube, the skin tube to the jejunum, and the jejunum to the stomach—all provide sites for the formation of fistulae and subsequent stenosis. The jejuno-esophagoplasty of Roux and Herzen has been popularized by Yudin's⁸ 11 successful cases. Not infrequently, however, the arrangement of the mesenteric vessels is such that sufficient viable jejunum cannot be mobilized to reach to the cervical region. Ochsner and Owens⁷ reported gangrene of the jejunal loop occurring in 22 per cent of the patients operated upon by this method.



FIG. 15.—Intestinal-skin tube transplanted to left anterior chest wall.

Other methods that have been used include the transfer of gastric tubes, migration of the entire stomach, or transplantation of a segment of the colon. In all of the methods thus far reported the transplanted portions of the alimentary tract have depended upon the original mesenteric vascular system for their blood supply.

The use of a segment of jejunum as a free graft eliminates many of the major objections to the previous methods in that it provides a channel lined with mucous membrane which has active peristalsis and which can be anastomosed directly to gastric mucosa with little fear of subsequent ulceration. Our method has the disadvantages of being time-consuming, and of requiring multiple operations. The first step, however, is the only really major operative procedure and carries only the risk inherent in any anastomosis of the small intestine. Most of the steps are minor plastic operations which expose the

ARTIFICIAL ESOPHAGUS

patient to very little risk and discomfort. Although our experience with this method has been limited, we believe it has certain advantages which justify a preliminary report.

SUMMARY

A new method for constructing an artificial antethoracic esophagus is described. This method was developed in experimental animals and has been used in the treatment of three patients with benign esophageal lesions. In this



FIG. 16.—Patient R. C., with intestinal-skin tube formed. Central pedicle and mesenteric vessels divided.

method an isolated segment of jejunum enclosed in a skin tube is transferred to the anterior chest wall to serve as a channel between the cervical esophagus and the stomach.

The use of a free jejunal graft allows the intestine to be transplanted wherever needed unrestricted by an attached mesentery. It provides a channel which is completely lined with mucous membrane and which has active peristalsis to aid in transporting the swallowed bolus to the stomach.

REFERENCES

- ¹ Garlock, J. H.: The Reestablishment of Esophagogastric Continuity Following Resection of the Esophagus for Carcinoma of the Middle Third. *Surg., Gynec. and Obst.*, **78**, 23, 1944.
- ² Sweet, R. H.: Transthoracic Resection of the Esophagus and Stomach for Carcinoma. *ANNALS OF SURGERY*, **121**, 272, 1945.

- ³ Clark, D. E.: Transthoracic Esophagogastrostomy for Carcinoma of the Middle Third of the Esophagus. *ANNALS OF SURGERY*, **121**, 65, 1945.
- ⁴ Puestow, C. B.: The Activity of Isolated Intestinal Segments. *Arch. Surg.*, **24**, 565, 1932.
- ⁵ Reagan, R. E., and Puestow, C. B.: The Activity of Isolated Segments of the Colon of Dogs: With Special Reference to the Influence of Certain Drugs. *Surgery*, **6**, 663, 1939.
- ⁶ Davis, J. S., and Stafford, E. S.: Successful Construction of an Extrathoracic Esophagus. *Bull. Johns Hopkins Hosp.*, **71**, 191, 1942.
- ⁷ Ochsner, A., and Owens, N.: Antethoracic Esophagoplasty for Impermeable Stricture of the Esophagus. *ANNALS OF SURGERY*, **100**, 1055, 1934.
- ⁸ Yudin, S. S.: The Surgical Construction of 80 Cases of Artificial Esophagus. *Surg., Gynec. and Obst.*, **78**, 561, 1944.

DISCUSSION.—DR. WILLIAM F. RIENHOFF, JR., Baltimore, Maryland: I personally wish to extend my sincere congratulations to Drs. Longmire and Ravitch on their most interesting fundamental contribution to the difficult problem of antethoracic esophagoplasty. I have recently made a rather complete review of the literature on the subject of esophageal surgery and have been impressed with the many different methods of reconstruction of the esophagus that have been employed in the past. Although alluring to the mechanical sense, the great majority of these procedures have been unsatisfactory for one reason or another. In my opinion the method of Longmire and Ravitch would seem to be the most satisfactory yet to be described.

The surgeon who deals with the problem of antethoracic esophagoplasty must be one of great versatility as well as virtuosity. However, different problems from a surgical technical standpoint are posed by different lesions of the esophagus. The time element must be taken into consideration particularly when one is dealing with malignant tumors of the esophagus in elderly people. Thus, the minimal number of operative procedures is to be preferred to one requiring multiple stages. It would seem that the ideal to be aspired to in the treatment of carcinoma of the esophagus would involve not more than two stages or operative procedures, with the reconstructed esophagus ultimately lying in the thoracic cavity in the bed of the resected esophagus. At the same time the reconstructed esophagus should consist of a tube approximating the normal esophagus in size.

In 1942, the intrathoracic transplantation of the jejunum was, I believe, accomplished for the first time and reported with other cases at the meeting of the American Association for Thoracic Surgery in 1944.* Mobilization of the jejunum was first suggested by Tavel, before 1900, in order to free a short loop of the jejunum to effect a permanent gastrostomy. In 1904, Wulstein proposed more extensive mobilization of the jejunum, sufficient to transplant a free loop subcutaneously extending from the abdomen to the pharynx. The operation was performed only on the cadaver until 1907, when Roux transplanted such a loop in a child suffering from lye stricture. Whether or not the final anastomosis was made between the jejunum and esophagus in this case could not be determined from Roux's report. Furthermore the ultimate result as to the success of the procedure was never published which, to my mind, cast some doubt on the probable end-result. Roux recommended division of the first five branches of the superior mesenteric artery, *i.e.*, the vasa recta, jejunalis, division of the jejunum just distal to Treit's ligament, followed by jejunojejunostomy between the proximal loop and the aboral portion of the distal loop. The mobilized loop of jejunum was then transplanted, as suggested by Wulstein, subcutaneously at once. This method, the Wulstein-Roux, fell into disrepute because such extensive mobilization of the jejunum necessary to reach from the posterior peritoneal wall, out and over the costal margin, up and along the thoracic cage to the level of the neck above the clavicle, resulted in a high percentage of gangrene of the oral end of the loop. It was realized that far less mobilization of the jejunum would be necessary if the freed loop was brought up transthoracically in the bed of the resected esophagus in order to traverse the distance from Treit's ligament

* *Jour. Thoracic Surgery*, Vol. 13, October, 1944, No. 5.

ARTIFICIAL ESOPHAGUS

to the dome of the thoracic cavity, a distance of 30 cm. It was found necessary to divide only three of the vasa recta jejunalis, the second, third and fourth, to obtain a sufficient length of intestine, 40 cm., to reach transthoracically to the dome of the chest cavity. Thus, the danger of jeopardizing the blood flow to the oral end of the mobilized loop is very much lessened.

I should like to report a case in which this procedure has been successfully carried out and which is, I believe, the first time such a transthoracic esophagojejunostomy has been done for carcinoma of the esophagus.

Case Report.—M. C., age 49, was referred to me by Dr. J. C. Dickinson, of Tampa, Florida. An early diagnosis had been made of a carcinoma of the esophagus at the level of the arch of the aorta. At the first stage the jejunum was mobilized by dividing the second, third and fourth vasa recta jejunalis. The intestine was divided about 6 cm. from Treit's ligament. The first vasa recta jejunalis was preserved. A jejunojejunostomy was then performed, end-to-side, between the open end of the proximal loop just distal to Treit's ligament and the aboral portion of the mobilized loop. The oral end of the mobilized loop was then closed with interrupted silk sutures and this end was fixed in the esophageal hiatus. The abdomen was closed. Three days later the chest was opened by resecting the seventh rib; the esophagus was resected, including a safe margin above the growth. The upper end of the esophagus was then brought out lateral to the aortic arch. An end-to-end anastomosis was performed between the jejunum and the esophagus. The fixation of the jejunum into the esophageal hiatus made it less difficult to locate this end when the chest was opened. There was no tension. The jejunum was brought out through the esophageal hiatus without the slightest difficulty. The tendinous portion of the diaphragm bordering this esophageal hiatus was incised to allow more freedom for drawing the jejunum into the chest. It has been a period of ten months, and this patient has remained perfectly well, being able to swallow ordinary meals; no special type of food or diet has been necessary.

DR. ALTON OCHSNER, New Orleans, La.: This method which Doctor Longmire has described is certainly ingenious. After an experience of six cases which Doctor Owens and I have had, using a jejunodermato-esophagoplasty, I am thoroughly convinced that this is much preferable to the one we used. The procedure we used is fraught with a good many technical difficulties. In our first case we performed 15 operative procedures. One thing Doctor Owens, who is our plastic surgeon, insisted upon is that the cervical portion of the operation not be done until after the skin tube had been formed. I think this is an important point because of the danger of interference with healing due to the cervical esophageal fistula. A great advantage of Doctor Longmire's procedure is that it produces a mucous membrane-lined tube which has active peristalsis. On the other hand, patients with a jejunodermato-anterothoracic esophagoplasty can swallow well. Peristalsis is not necessary. They were able to swallow through propulsive force of the pharyngeal muscles.

EXPERIENCES IN SUBTOTAL RESECTION OF THE PANCREAS IN HYPOGLYCEMIA*

VERNON C. DAVID, M.D., AND LEO K. CAMPBELL, M.D.

CHICAGO, ILL.

FROM THE SURGICAL DEPARTMENT OF THE PRESBYTERIAN HOSPITAL AND
THE UNIVERSITY OF ILLINOIS COLLEGE OF MEDICINE.

SINCE the fundamental suggestion of Harris¹ and the first case report of Wilder,² the importance of islet tumors of the pancreas as a cause of hypoglycemia has increased with added experience. In a report, in 1944, Whipple³ collected 149 cases from the literature, including his own, where small adenomas of the islet tissue or carcinoma arising from the same cells had been removed surgically, with cure or great improvement of the disturbed sugar metabolism. It has been learned from experience that the tumors may be single or multiple, they may occur in the head of the pancreas as well as in the tail, and they also are occasionally found in aberrant pancreatic tissue or in an accessory pancreas. Hyperplasia of the duct cells of the islands of Langerhans may also be associated with hypoglycemia.

The symptoms of hypoglycemia are numerous but, as Whipple has pointed out, they arrange themselves rather definitely into three categories: (1) During an attack, the fasting blood sugar is below 50 mg. per cent. (2) The patient may experience a great variety of nervous symptoms varying from weakness or fainting and muscular irritability to amnesia or tonic or clonic convulsions. (3) During an attack, the administration of large amounts of sugar relieves the symptoms.

Among the causes of hypoglycemia in any given patient it is extremely important to consider the possibility of lesions of other organs and glands which are known to influence sugar metabolism as the liver, adrenal, hypophysis, and thyroid. The symptoms of hypoglycemia may also be found in patients with an unstable nervous system, and here the importance of Whipple's triad is helpful in differential diagnosis. The purely dietary management of hypoglycemia⁴ should always be tried before surgery is resorted to.

Careful selection of cases by exclusion, as far as possible, of other causes of hypoglycemia leads to an indication for surgical removal of the islet cell tumor. This program has resulted in many cures, with a surgical mortality of about 15 per cent. The causes of the failures frequently have been discovered at a subsequent operation or at autopsy where a small adenoma has been found in the head of the pancreas or buried in its substance, or occasionally found in an accessory pancreas or in aberrant pancreatic tissue.

There is, however, another small group of patients who have the classical symptoms of hypoglycemia presumably due to an islet tumor of the pancreas

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

PANCREATECTOMY IN HYPOGLYCEMIA

but in whom no tumor is found after careful exposure of all available parts of the pancreas at operation. The purpose of this paper is to discuss this problem, particularly from the viewpoint of the advisability of performing a subtotal pancreatectomy at the time of exploration.

In 1935, I⁵ reported a typical example of this particular group where a patient having a very severe hypoglycemia with convulsions was operated upon and in the absence of a tumor of the pancreas, 49 grams of pancreas was resected, with complete relief of symptoms up to the present time (Fig. 1). In that report, the literature was carefully reviewed and all patients having a small or large portion of the pancreas removed for hypoglycemia were studied. It was found that in the patients answering the criteria necessary for surgical intervention 18 had a small amount of the tail of the pancreas (8 to 28 Gm.) removed with very little effect on the course of their illness. On the other hand, 14 patients who had 40 Gm. or more of pancreas removed were completely relieved of their symptoms, with an operative mortality of one patient.

Since that report,⁵ we have had the opportunity of operating upon two additional patients with hypoglycemia where no adenoma was found on careful examination of the pancreas and a massive resection of the pancreas was carried out. A review of the literature up to a recent date has added a number of other cases falling into this group so that the records of 36 patients are now available for review.

TABLE I

36 CASES WITH HYPOGLYCEMIA. AT OPERATION NO LESION OF THE PANCREAS WAS FOUND.
MASSIVE RESECTION OF THE PANCREAS PERFORMED.

	No. of Cases	Cured	Slight or No Improvement	Died
Adenoma*	5	5		
Hyperplasia of islets	6	3	3	
Normal pancreas histology	25	15	8	2
	36	23 (63%)	11 (31%)	2 (6%)

* In five patients, an adenoma of the islet tissue was found in the resected portion of the pancreas, and all five of these patients completely recovered.

In a patient reported by Frantz,⁸ two previous operations had been performed and an adenoma removed at each operation before Whipple undertook the third operation because of persistence of symptoms. He resected the body and a portion of the head of the pancreas and discovered five small adenomas in the resected tissue. Priestley, Comfort, and Radcliffe,⁷ being unfavorably impressed by the poor result obtained on a patient, operated upon by Rynearson, by massive resection of the pancreas, performed a complete pancreatectomy on a patient and found an adenoma 8 x 5 x 5 mm. in the head of the pancreas. The patient was cured of the symptoms of hypoglycemia and required 66 units of insulin a day to control the diabetes.

There were six patients in whom a massive resection of the pancreas was performed and a study of the resected tissue revealed hyperplasia of the islet tissue.

TABLE II

SUBTOTAL REMOVAL OF APPARENTLY NORMAL PANCREAS.
SMALL ADENOMA FOUND IN RESECTED PANCREAS

Author	Publication	Age	Whipple Triad	Operation	Pathology	Result
1. Frantz, V. K.	Ann. Surg., 119; No. 6, 824, June, 1944	46 yrs.	+	1st by McDonald Feb., 1942. Adenoma removed 2nd—May, 1942. Only temporary improvement 3rd by Whipple July, 1942. Body and portion of head removed. 5 adenomas found	Adenoma	Cured
2. Frantz, V. K.	Ann. Surg., 119; No. 6, 824, June, 1944		+	Tail and half of body removed by Dr. St. John. Small pancreas	2 small adenomas	Cured
3. Priestley, J. T., Comfort, M. W., and Radcliffe, J.	Ann. Surg., 119; 211, Feb., 1944		+	Total pancreatectomy	Small adenoma 8x5x5 mm. in head	Diabetic, 66 units of insulin necessary
4. Wangenstein, O.	Minn. Med., 18; 265, 1935	37 yrs.	+	Two-thirds pancreas removed	Adeno- carcinoma	Cured 3 years
5. Engle, L. P.	Personal com- munication to A. O. Whipple	38 yrs.	+	Subtotal removal	Adenoma in tail	Well 10 months

TABLE III

SUBTOTAL REMOVAL OF PANCREAS. NO TUMOR FOUND. DEFINITE HYPERPLASIA OF THE ISLETS OR SMALL ADENOMA.
FOUND IN RESECTED PANCREAS

Author	Publication	Age	Duration Symptoms	Blood Sugar	Operation	Pathology	Result
1. Simon, H. E.	So. Surg., 3; 199, 1934	26 yrs.	3.5 months. Unconscious- ness	51 mg. %	60 grams pancreas removed	Hyperplasia of islets	Well 3 years. Died from ac- cident
2. McCaughan, J. L., and Brown, G. O.	Ann. Surg., 105; 354, 1937	20 yrs.	Convulsions	70 mg. %	35 grams removed	Hyperplasia of islets	Recur- rent symp- toms
3. H. Harris (Drennan)	So. Surg., 3; 199, 1934	27 yrs.	4 months	65 mg.			Unim- proved 4 years
4. Maxeiner, S. R., and Bundy, H. E.	Surgery, 18; No. 2, 171, 1945		Hypoglycemia. Nervousness		45 grams removed	Hyperplasia of islets re- sembling minute adenoma	Cured
5. Leriche, R., and Schneider, H.	Presse Med., 49; 561, May 28, 1941	42 yrs.	Hypogly- cemia. Nervousness	60 mg. %	10-cm.-long long piece of tail and body. Op. 1937	Hyperplasia of islet cells	Cured 3 years
6. Frantz, V. K.	Ann. Surg., 119; No. 6 June, 1944				Whipple triad One-half pancreas removed. Op. by Whipple	Hyperplasia of islets	No im- prove- ment

PANCREATECTOMY IN HYPOGLYCEMIA

TABLE IV
SUBTOTAL RESECTION OF PANCREAS. PANCREAS FAIRLY NORMAL.
NO TUMOR FOUND

Author	Publication	Age	Duration Symptoms	Whipple Triad	Result
1. Harris, S. (Taylor)	J.A.M.A., 100 ; 321, 1933	20 yrs.	2 yrs.	+	Well, 6 yrs.
2. Graham, E. A., and Hartman, H. F.	Surg., Gynec., & Obst., 59 ; 474, 1934	1 yr.	9 mos.	+	Symptom free 4 yrs.; mentally deficient
3. Harris, S. (Drennan)	South Surg., 3 ; 199, 1934	32 yrs.	?	+	Symptom-free 4 yrs.
4. Thonason, G.	West. J. Surg., 43 ; 188-192, 1935	43 yrs.	3 yrs.	+	Symptom-free 4 yrs.
5. Reinhoff, W. F., and Lewis, Dean	Bull. Johns Hopkins Hosp., 386, 1934	39 yrs.	18 mos.	+	Died first postoperative day
6. McCaughan, J. M., and Brown, G. O.	Ann. Surg., 105 ; 354, 1937	26 yrs.	24 yrs.	+	Recurrent symptoms
7. Engel, L. P.	Personal communication to Whipple	55 yrs.		+	Symptom-free 7 yrs.
8. Womack, L. A., and Cole, W. H.	Ann. Surg., 105 ; 370, 1937	36 yrs.	4 yrs.	+	Cured
9. Womack, L. A., and Cole, W. H.	Ann. Surg., 105 ; 370, 1937	26 yrs.	3 yrs.	+	Cured
10. Clarke, J. M.	Australian & New Zealand J. Surg., 8 ; 66-73, 1938			+	Cured
11. Engel, L.	Personal communication			+	Cured but low blood sugar

TABLE IV—Continued

Author	Publication Personal communication	Age	Duration Symptoms	Whipple Triad	Operation	Pathology	Result
12. Womack, L. A.				+			No improvement
13. Carrol, W. C.	Minnesota Med., 20; 229, 1937	30 yrs.	9 mos.	+			Improved; nervous
14. Berry, J. G.	Brit. Jour. Surg., 23-51, July, 1935	28 yrs.	14 yrs.	+	Tail and part of body re- moved. 28 gra. Body, tail and islets were splen by R. Graham, Nov., 1938	Normal histo- logically Islets were numerous Cells varied	Cured 8 mos.
15. Wagner, W.	Canad. Med. A. Jour., 40-49, July, 1941	20 yrs.		+			Cured 6 mos.
16. Ryneerson, E. H., and Walters, W.	Proc. Staff Meet. Mayo Clinic, 13; 728, Nov. 16, 1938	32 yrs.	10 yrs.	Con- vul- sions	One-half pan- creas removed. 2nd—Judd. Nodule removed 3rd—Authors. Removed all pancreas except small piece near the ducts	Normal	No im- prove- ment
17. Frantz (1) (op. by Dr. A. Whipple)	Ann. Surg., 119; No. 6, 824, June, 1944		Hypo- gly- cemia	Blood sugar below 42	One-half pan- creas removed	Hyper- plasia	Blood sugar rose from 42 to 46
18. Frantz (2)	Ann. Surg., 119; No. 6, 824, June, 1944		Hypo- gly- cemia	Blood sugar below 50	One-half pan- creas removed	Normal	No im- prove- ment
19. McClure, Roy, and Brush, B. E. (1)	Ann. Surg., 120; 750, Nov. 1944	19 yrs.	11 mos. Weakness, sweating, tremor	55 mg. %	Two-thirds pancreas removed	Normal	Cured 2 mos.
20. McClure, Roy, and Brush, B. E. (2)	Ann. Surg., 120; 750, Nov., 1944	43 yrs.	13 yrs. Weakness, nervousness, excessive hunger	60 mg. %	Five-sixths pancreas removed	Normal	Cured 2 yrs.

PANCREATECTOMY IN HYPOGLYCEMIA

TABLE IV—Continued

Author	Publication	Age	Symptoms Duration	Blood Sugar	Operation	Pathology	Result
21. Wechsler, L. S., and Garloch, J. H.	J. Mt. Sinai Hosp. 10; 704, Jan.-Feb., 1944	36 yrs.	Weakness, nervousness	20 mg. %	Body and tail removed	Normal	No im- prove- Bl. sugar 30.2 yrs. after Cured 7 yrs.
22. David, V. C., and Woodyatt, R. T.	Surgery, 8; 2, 212-224, Aug., 1940	21 yrs.	Clonic and tonic con- vulsions	Below 60 mg. %	Body and tail, 48 grams, re- moved. May, 1938	Normal	Recovery and cure, except some diarrhea. Sugar tolerance normal
23. David, V. C., and Woodyatt, R. T.	See text.	40 yrs.	Nervous- ness, con- vulsions, worry, 3 yrs.	Below 60 mg. %	Body and tail of pancreas (38 grams) and spleen removed, Mar. 18, 1941	Normal	No im- prove- ment
24. David, V. C., Woodyatt, R. T., and Campbell, L.	See text		Unconscious- ness, convul- sions, sweat- ing, mental symptoms	20 mg. %	1st op. Body and tail of pancreas (28 grams) and spleen removed. Pancreas small and atrophic. 2nd op. All but 3-4 grams pancreas removed	Normal	Died 3rd day. Bl. sugar after 60 grams glucose
25. Barnes, J. A.	New England J. Med., 213; 225, Aug. 1, 1935	35 yrs.	Hypogly- cemia, nervousness, 18 months	35 mg. %	2 inches pancreas removed	Normal	Unim- proved 4 yrs.
*26. Harris, S., and Drennan	South. Surg., 3; 199, 1934	27 yrs.	Convulsions 4 months	65 mg. %	One-half body and tail removed		

* Questionable case due to relatively high blood sugar.

Only three of these patients were relieved of their symptoms and two of these have been followed three years.

The most interesting group consists of 25 patients whose resected pancreas was normal histologically.

Following operation, two of these patients died, six had no improvement, and 15 (60 per cent) were cured of their symptoms of hypoglycemia. Eight of the patients have been followed for two to seven years. Ryneerson and Walters had a very disappointing result in a patient, one-half of whose pancreas had been previously removed by Holman and had been subsequently explored by Judd. At the third operation, all of the pancreas except a small piece near the entrance of the duct into the duodenum was removed without improvement to the patient. Our third patient to be reported had a similar unfavorable result after almost complete pancreatectomy. In contrast to the unfavorable results recorded, there still remain 60 per cent of the patients who were cured of their symptoms of hypoglycemia by massive resection of the pancreas where grossly and histologically the pancreas appeared normal. I can offer very little logic as to why this should be true but faced with a critically sick patient where hyperinsulinism appears to be responsible for the hypoglycemic state and upon careful exploration of the pancreas no tumor is found, I am impressed with the advisability of resecting a major portion of the pancreas. Under such conditions, 23 of the 36 patients reviewed in this study were cured.

The report of the two additional cases of our own offer a marked contrast to each other. The first patient was almost a replica of our previously reported case. A typical hypoglycemia with convulsive seizures with a fasting blood sugar of 50 mg. per cent and relieved by administration of sugar was completely relieved of her symptoms (with the exception of a functional colitis) by removal of 45 Gm. of the tail and body of her pancreas and her spleen. Histologically the pancreas was normal. (Fig. 2)

The third patient was the most seriously ill of the three, requiring supplementary feedings of glucose every four hours and with a blood sugar during an attack of 20 mg. per cent or so low it was unreadable. This patient had the appearance of an hypohypophyseal dyscrasia but roentgenograms of the sella showed but slight thinning of the postclinoids and roentgenotherapy of the region of the hypophysis gave no relief. At operation, the liver and adrenals were normal and there was no evidence of an accessory pancreas. The pancreas was small and atrophic and when removed to a point just to the right of the superior mesenteric vessels, the resected specimen weighed only 28 Gm. Histologically, the resected pancreas was normal (Fig. 2). The patient recovered well from her operation but there was little or no change in her clinical picture or in her sugar metabolism. At this stage, Dr. Leo Campbell decided to give the patient Alloxan parenterally, based on the necrotizing effect it had shown on the islet tissue in animals and its use by Brunschwig in a patient with a carcinoma of the islet tissue who had hypoglycemia. High doses were given with some reluctance without effect.

Six months having elapsed and the patient being in much the same condition, reoperation was decided upon, at which time, with some difficulty, the remainder of the pancreas was largely removed leaving perhaps 3 to 5 Gm. closely adherent to the duodenum. This tissue was also normal histologically and contained no tumor tissue. Following this operation, the patient required less sugar for a week and at one time had sugar in the urine at ten drops of reducing agent. However, in a few days the *status quo ante* was resumed and the patient today is as much of a problem as ever.

CASE REPORTS

Case 1.—Miss W. N., age 40, was first admitted to the Presbyterian Hospital in December, 1938, on Dr. Rollin T. Woodyatt's service with the following complaints: (1) Twitching and shaking of the lower extremities for two weeks; (2) attacks of nervousness and tenseness accompanied by loss of strength beginning two weeks previous to admission; (3) anorexia for three years; (4) loss of weight, ten pounds; and (5) excessive worry.

The blood sugar was 50 mg. per cent at its lowest point. Her symptoms were relieved by the administration of large amounts of glucose. Her general examination, roentgenograms of the gastro-intestinal tract, metabolic rate, and blood chemistry were normal, with the exception of her glucose tolerance. A diagnosis of spontaneous hypoglycemia was made. Between 1938 and 1941 she was hospitalized five times, and given treatment. In March, 1941, she returned for surgical treatment, inasmuch as her condition had become worse.

At operation, March 18, 1941, under gas-ether anesthesia, through a transverse upper abdominal incision, the pancreas was found to be rather small. It was thoroughly explored, including reflexion of the duodenum to the left so that the head could be thoroughly examined, and no tumor was found. A resection of the body and tail of the pancreas was done, removing 38 Gm. of pancreas, to a point somewhat to the right of the superior mesenteric vessels and leaving a piece of pancreas in the concavity of the duodenum the size of a walnut. It was estimated that five-sixths of the pancreas was removed. One cigarette drain was left after bringing the cut surfaces of the pancreas together by interrupted silk sutures. The patient recovered easily from her operation and since that time to the present has had no return of her symptoms of hypoglycemia and has a normal blood sugar and glucose tolerance. She does complain of attacks of diarrhea which are controlled by a bland diet. There is no fat indigestion. The pathologic examination of the resected pancreas revealed no adenoma of the islet tissue. The islet tissue appeared normal.

Case 2.—Mrs. B. L., age 47, was a patient of Drs. Leo Campbell and Rollin T. Woodyatt. For a number of years she had been drowsy much of the time, sweated easily, and had headaches. Three years ago she went through the menopause. Two years ago she came to the Presbyterian Hospital in coma and was revived by intravenous glucose injection. She had to be awakened each morning at 5:00 A.M. to be given sweetened fruit juice to prevent coma. A year ago her blood sugar was 40 mg. per cent, and she began to have convulsions and became irrational unless given frequent feedings of sugar.

On examination, her metabolic rates were from -5 to -10 . The roentgenograms of her sella showed some thinning of the postclinoïd processes. Her optic disks were normal. Her fasting blood sugar was 30 mg. per cent. She was given roentgenotherapy (3,000 R) over the hypophysis without result.

On May 26, 1944, she was explored through an upper transverse abdominal incision, under gas-ether anesthesia.

General exploration of the abdominal contents revealed no particular pathology. The pancreas was smaller than normal and uniformly firm. Thorough examination of

the tail, body, and head, after rotating the duodenum medially, revealed no tumor. All of the pancreas to the left of the superior mesenteric vessels was removed. It weighed only 28 Gm. The spleen was normal and was also removed due to ligation of the splenic vessels in removal of the pancreas. The cut-surface of the pancreas was repaired by interrupted silk. One Penrose drain was left.

The pathologic examination of the pancreas showed no abnormalities in the islet tissue.

A few days after operation, the blood sugar was 50 mg. per cent. On one examination there was a trace of sugar in the urine with ten drops of reducing agent, but in a short time the patient was in the same condition as before operation and required feedings of sugar every four hours to keep her out of coma and convulsions. One month later, Doctor Campbell began treating her with Alloxan. Alloxan is the ureid of mesoxalic acid. It is given in 1 per cent solution at the rate of 3 cc. per minute. In rabbits and dogs not only are the islands of Langerhans necrosed by its use but transient degeneration of the kidney tubules and of the liver is also observed. In animals the dosage is 100-150 mg. of Alloxan per kilogram body weight. In dogs treated with Alloxan there ensues a short period of hyperglycemia followed by a severe hypoglycemia, with convulsions.

Treatment of this patient by Alloxan was given June 29 and 30 and July 1, 1944, giving her 150 mg. per kilo of body weight, or a total of 450 mg. Not only was there no change in the hypoglycemic state but her reactions were more severe and frequent.

Adrenal cortex (Wilson's crude) 3 cc. every six hours was given for three weeks without any evident effect.

On November 17, 18 and 19, 1944, she was given Alloxan, 250 mg. per kilo body weight. Seven days later the blood sugar was as low as 30 mg. per cent and she was still having severe reactions. There was no evidence of liver or kidney damage.

On January 24, 25 and 26, 1945, Alloxan was given in 250 mg. doses per kilo of body weight without effect. The N. P. N. of the blood remained normal but the Hanger test for liver function became weakly positive but became negative after a week. The prothrombin was 90 per cent.

On March 1, 1945, she was given 2 cc. of Armour's Growth Hormone (pituitary diabetogenic) and this was continued for nearly three weeks without demonstrable effect.

From April 7, 1945 to May 10, 1945 she was given 9 gr. of desiccated thyroid a day without influence on the hypoglycemic attacks. This was given because permanent diabetes was produced by Housay in dogs with transient diabetes from partial pancreatectomy when sustained large doses of thyroid was administered.

From May 10 to July 8, 1945, the patient was given 15 cc. daily of crude liver (1 cc. = 1 unit) because hypoglycemia glycosuria has been reported in individuals receiving large doses of the crude extract. This medication produced no change in the hypoglycemic attacks in this patient.

Because of the continuing desperate condition of the patient, it was decided to reoperate upon her. On July 21, 1945, under gas-ether anesthesia, a transverse incision was made above the umbilicus. Due to the marked adiposity of the patient and obliterating adhesions from the previous operation, the mechanical problem was tedious, but the pancreas was separated from the superior mesenteric vessels and portal vein and all of it was removed but a very small portion next to the duodenum where the pancreatic duct entered the duodenum. No adenoma was found grossly or histologically in the resected portion and the islet tissue appeared normal or slightly hyperplastic in spite of the large doses of Alloxan the patient had received.

The abdomen was closed with silk technic with one Penrose drain, and the patient recovered without serious complication. Unfortunately, her hypoglycemia persists and the subtotal removal of her pancreas has had no effect on the course of her disease as she now requires frequent feedings of glucose to prevent the symptoms of syncope and convulsions.

PANCREATECTOMY IN HYPOGLYCEMIA

She is now being given a crude oil extract of the hog adrenal cortex, which is reported to contain compound "E," which was discovered by Kendall and shown to produce hyperglycemia in animals.

CONCLUSIONS

In patients with symptoms of serious hypoglycemia where surgical intervention is indicated and upon careful examination of the pancreas at operation no pathology is found, it appears indicated to undertake a massive resection of the pancreas at that time.

Thirty-six patients in this category were so treated with 23 recoveries from their symptoms, and two deaths.

In 25 patients, the resected pancreas showed no pathology, and 15 of these patients apparently were cured.

Large doses of Alloxan failed to change the course of the hypoglycemic state in one patient.

REFERENCES

- ¹ Harris, S.: J. A. M. A., **83**, 729, 1924.
- ² Wilder, R. M., Allen, F. N., Power, M. H., and Robertson, D. E.: J. A. M. A., **89**, 348, 1927.
- ³ Whipple, Allen O.: Surgery, **8**, 289, 1944.
- ⁴ Conn, J. W., and Conn, E. S.: Am. Soc. for Clinical Investigation, May, 1940.
- ⁵ David, V. C.: Surgery, **8**, 212, 1940.
- ⁶ Rynearson, E. H., and Walters, W.: Proc. Staff Meet. Mayo Clinic, **13**, 128, November 16, 1938.
- ⁷ Priestley, J. I., Comfort, M. W., and Radcliffe, J.: ANNALS OF SURGERY, **119**, 211, February, 1944.
- ⁸ Frantz, V. K.: ANNALS OF SURGERY, **119**, No. 6, 824, June, 1944.

DISCUSSION.—DR. ALLEN O. WHIPPLE, New York, N. Y.: Our experience with this subject is based upon some 39 patients who have been operated upon, in whom we have found tumors in 33. I wish to emphasize three or four points in connection with the subject. One is the importance of adequate exploration of the pancreas. In the hands of such able surgeons as Doctor David, the finding of tumors of the pancreas will be successful in a very high percentage of cases. On the other hand, I cannot help but emphasize the importance of mobilizing the duodenum in order to expose the head of the pancreas on both sides. We have reoperated upon six patients with the finding of tumor in the head of the pancreas. The sense of feeling a mass in the tip of the pancreas after mobilizing the duodenum is so positive that one can almost be satisfied that the finding of the tumor under these conditions will be positive.

We have resected some nine cases, largely in our early cases, with not too good results, probably for two reasons; we probably overlooked the tumor, for one; and secondly, we did not resect enough of the pancreas in cases where the tumor was not present. In three cases that were resected I have reoperated and found a tumor in the head of the pancreas. These patients have been relieved of symptoms.

The second point I want to bring out is to call your attention to the very interesting and unexpected result in total pancreatectomy. I am sure it has given hours of concern and anxiety to physiologists. They cannot understand it. But a sufficient number of cases has been done to show that total pancreatectomy is compatible with life. Patients do not require as much insulin as you would expect. One requires only 40 units. They do not necessarily have altered or abnormal stools and the results are astoundingly better than one would expect. We have performed two total resections; one patient is living more than a year after operation and has done well. The second

case did not survive the operation but died on the third day; the cause of death could not be determined at autopsy.

The third point is the failure of alloxan. We have had no success with it, and I am interested in Doctor David's report. It does result in amelioration, in dogs, but it causes kidney damage, and in the absence of results in clinical cases I am afraid that method of treatment will be of no avail.

I wish to congratulate Doctor David for following-up on his first paper and collecting the data as he has.

INDICATIONS FOR AND VALUE OF CHOLEDOCHODUODENOSTOMY*

R. L. SANDERS, M.D.

MEMPHIS, TENN.

AT BEST, side-tracking operations for obstruction of the bile ducts are fraught with many difficulties and dangers. The abdomen is frequently filled with adhesions, hemorrhage may be troublesome, and identification of the ducts and vessels is often a time-consuming process. Added to this, patients with a long history of duct obstruction usually present a deep jaundice with an alteration in the blood clotting time, loss of weight and strength, and advanced renal and hepatic changes. Under these circumstances, the operation should be selected with a view to its simplicity and the earliest possible restoration of normal biliary drainage.

We have been impressed with the results of choledochoduodenostomy, when feasible, as a means of relieving obstructions of the common duct. The procedure is not only comparatively simple from the standpoint of technic, but is physiologic in principle and, thus, offers a wide margin of safety. All the bile is immediately made available in that portion of the intestinal tract where it normally empties, intestinal function is soon restored, and the patient's convalescence is thereby facilitated.

Another important advantage of choledochoduodenostomy lies in the fact that the intraluminal pressure between the biliary tree and the intestinal tract appears to be equalized following operation. Ravdin and Frazier³ have pointed out the danger of the rapid release of obstruction of the ducts, not merely from the loss of bile, but rather from the abrupt increase in intrahepatic pressure. They have observed that intraductal pressure incident to obstruction leads not only to pathologic changes in the liver, but to venous stasis. The rapid release of the obstruction, with the sudden flow of blood into the impaired hepatic vessels may give rise to intense hyperemia, with further circulatory disturbance and additional damage to the liver. The situation is analogous to the renal and circulatory collapse which at times has occurred following sudden decompression of the bladder and urinary tract. This effect, manifested by serious toxic symptoms, has been observed in deeply jaundiced patients following choledochotomy and drainage to the surface. With the use of choledochoduodenostomy, decompression of the ducts takes place more slowly; thus, the ductal pressure is equalized by that in the intestinal tract and this complication is avoided.

Fortunately, choledochoduodenostomy is applicable to most benign lesions and to many malignancies of the ducts and pancreas. The first criterion for the operation is that the duct must be sufficiently large to permit an adequate stoma.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

Second, the duct must be of ample length above the obstruction to permit anastomosis without tension, or, one must be able to mobilize the duodenum to a sufficient extent. If the duct is not enlarged and the condition of the gallbladder and cystic duct permits, cholecystojejunostomy is preferable. The latter procedure is usually more applicable to malignancies of the head of the pancreas wherein the gallbladder is not diseased, the common duct is not appreciably enlarged, and the cystic duct is patent. When the gallbladder has been removed, or when it is not suitable, choledochoduodenostomy is obviously one's only recourse.

We feel that the use of the gallbladder for anastomosis in the presence of infection is contraindicated. The gallbladder is a poor conductor of bile, and the infectious process induced by chronic bile stasis cannot be counted upon to become quiescent and remain so; if the infection and inflammation persist, the walls become thickened, closing the stoma and leading to a recurrence of the biliary obstruction. For the same reason, one cannot depend upon the continued patency of the cystic duct in such cases. By eliminating the gallbladder, draining the common duct, then uniting it to the duodenum, one has every assurance of the free passage of the bile into the intestinal tract and the permanent relief of the patient's symptoms.

Within recent years, we have become convinced of the superiority of choledochoduodenostomy in the presence of an enlarged duct containing multiple stones, sand and muddy material, when the distal end of the duct is small and almost strictured. In such cases, it is difficult to dilate the distal end sufficiently to insure *continuous* and *ample* drainage. Moreover, the dilated area tends to contract again and bring about another impediment to the outflow of bile. This leads to the reformation of the stones and sandy material, the original clinical picture is reproduced, and a second operation becomes necessary. Such a condition frequently develops even after choledochostomy. Following choledochoduodenostomy, on the other hand, there is little likelihood of the reaccumulation of sand and stones. The distended duct lends itself well to the creation of an anastomosis sufficiently wide practically to insure continued and adequate drainage.

Two of our cases have strikingly demonstrated to us the desirability of this type of operation as a primary procedure when the common duct is distended, partially or wholly strictured, and difficult to dilate fully. One of these cases was that of a patient who was operated upon five years ago for cholecystitis with stones and perforation. The common duct was almost as large as the duodenum and was filled with stones and thick, sandy bile. The hepatic duct, also, contained a number of stones. The gallbladder was removed, the ducts evacuated and cleansed, and the distal end of the common duct dilated with a No. 8 Sanders-Bakés dilator. A T-tube was inserted and left in place for 17 days. The patient remained well for four years. Thereafter, he began having attacks of mild epigastric pain and discomfort, chills and fever, and faint jaundice. The attacks became more frequent and more severe, until it was necessary to submit him to exploration. On opening the abdomen, the common duct was

CHOLEDOCHODUODENOSTOMY

again found to be greatly enlarged and filled with stones and sand. These were removed and the duct was anastomosed to the duodenum. Six months have elapsed since the operation and thus far the patient has been entirely free of his former symptoms.

The second patient was a woman, age 61, who had chronic cholecystitis with obstructive jaundice. The gallbladder was quite diseased, but contained no stones. Small bile cysts and biliary abscesses were scattered throughout the

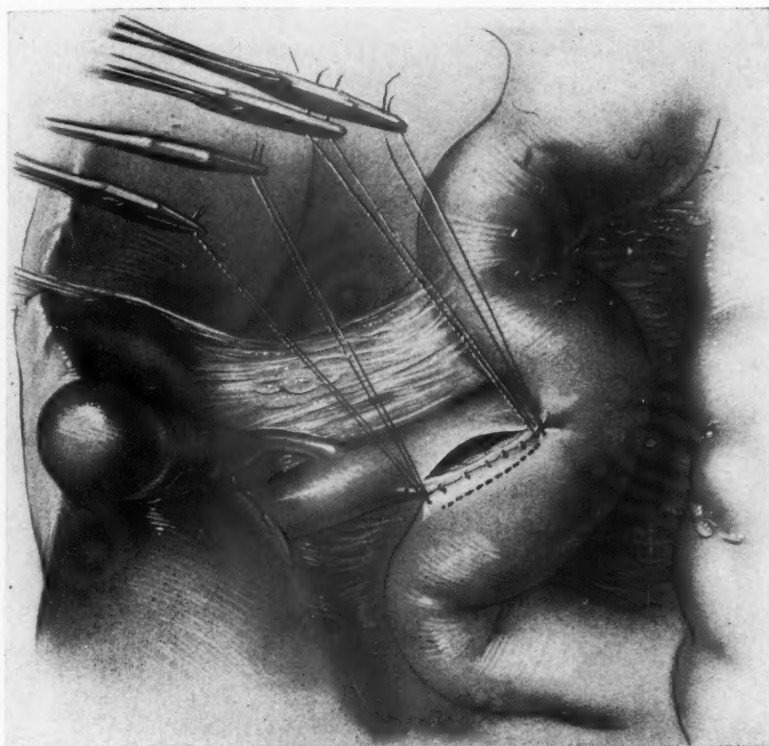


FIG. 1.—The greatly enlarged common duct has been opened, the stones, sand and muddy material removed, and a futile effort made to dilate the distal end. A row of interrupted sutures of fine silk have been placed in the serosa posteriorly. The dotted line shows the site of the incision in the duodenum. The traction sutures have been left at each end to afford better exposure of the suture line. The gallbladder is shown, though it should be removed before the common duct is opened, as a precaution against the passage of stones from the gallbladder into the duct.

liver. The common duct was five or six times normal size but no stones could be palpated. After removal of the gallbladder, the common duct was aspirated and then opened, and a large quantity of muddy bile filled with sand and numerous small stones was removed. The hepatic duct was thoroughly explored, though no stones were found. The distal end of the common duct was dilated and a T-tube left in the duct. Bile drained through the tube for two weeks and, following its removal, continued to drain through the incision. The stools had practically no color, showing that most of the bile was coming to the

surface. The patient also became slightly jaundiced. Apparently, the distal end of the duct was again obstructed. The fistula persisted, and five months after the first operation the abdomen was reopened and the fistula followed down to the common duct. The duct was still quite distended, and when opened, a large amount of thick, sandy material escaped, with many small stones from the hepatic duct. After a thorough cleansing of the ducts, an attempt was made to pass dilators through the papilla of Vater, but without success on account of a severe pancreatitis. The duodenum was then freed and widely anastomosed to

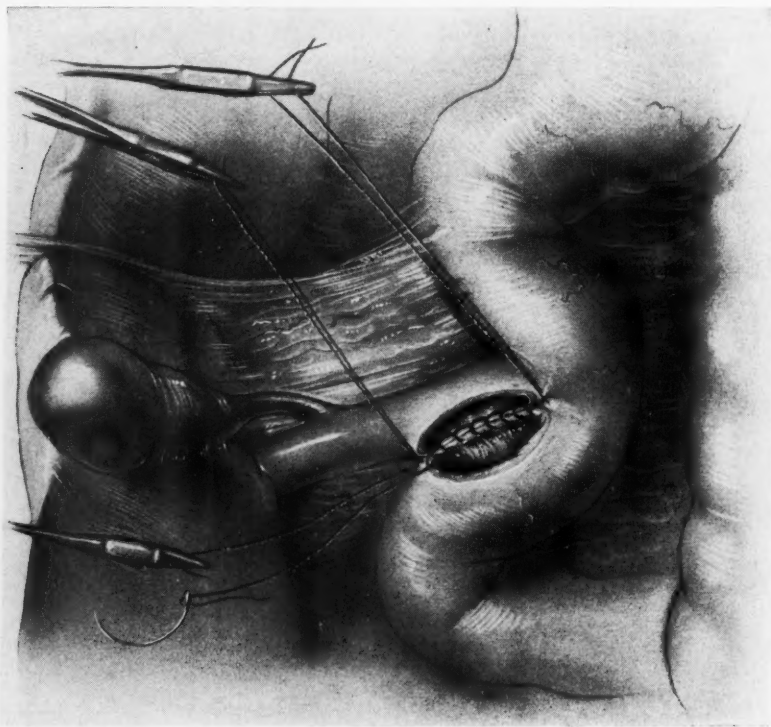


FIG. 2.—The duodenum has been opened and the mucosal layers of the duct and duodenum have been united posteriorly by a row of catgut sutures. The anastomosis is made as close to the duodenum as possible, in order to prevent angulation of the duodenum at the part nearest the liver.

the duct above the sinus. The anastomosis functioned perfectly, all the bile passing into the intestinal tract, and the jaundice cleared within a few days. The patient had no further disturbance referable to the biliary tract to the time of her death from another cause, three years later.

Incidentally, from the excellent symptomatic result in this case, it is apparent that there was no ascending infection into the biliary tree because of its connection with the intestinal tract.

A few of our experiences have demonstrated that choledochoduodenostomy is not only an advantageous operation but at times may be the means of saving a patient's life. A case in point was that of one of our most recent patients with

duct obstruction, a man, age 62, who had had a cholecystostomy nine years before for a gangrenous gallbladder containing stones. He had since had recurrent attacks of epigastric pain with jaundice. Six weeks previously, he had had another attack of pain, with chills and fever, and his stools had become putty-colored. At examination, he was extremely jaundiced, and a draining sinus led to the surface from the former cholecystostomy. On exploration, the gallbladder and cystic duct were distended and the common duct was almost as large as the duodenum. When the duct was opened, a quantity of purulent

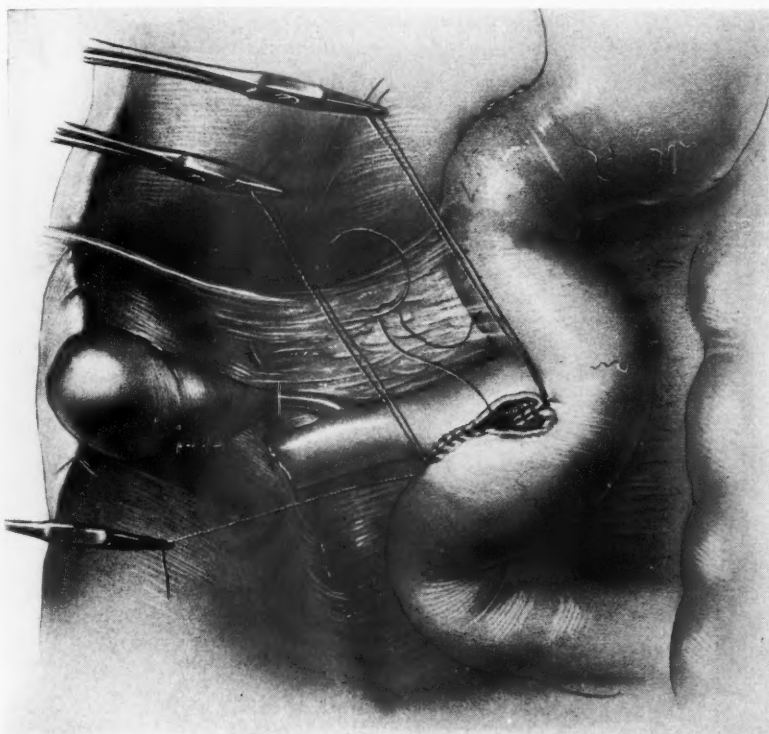


FIG. 3.—The anterior row of sutures is being placed to unite the mucosa of the duct and duodenum. This should be done without tension, though if the duodenum is properly mobilized in the beginning of the operation, there should be practically no tension.

material escaped and continued to pour out for a considerable time after the duct was emptied. This was not the typical white bile often seen in such cases, but was definitely a purulent fluid. Apparently, the liver had lost its power to secrete bile. The liver was not enlarged, but was bluish in color, incident to back pressure over a long period of time. There were no stones in the duct, but a firm mass as large as a lemon was palpated in the head of the pancreas; we could not determine whether this mass was due to pancreatitis or to a stone which had lodged there many years before. Fearing hemorrhage, the mass was not opened. After removal of the gallbladder, the common duct was thoroughly cleansed and anastomosed to the side of the duodenum. The patient made an

excellent recovery. Bile drained into the intestinal tract, the jaundice cleared and the wound healed primarily. It is more than likely that the outcome would have been fatal without this type of operation, which overcame the obstruction, allowed ample drainage of the purulent material, relieved intraductal tension, and permitted early restoration of liver function.

Except in injuries of the duct, or when a portion has been removed, it is our custom to make a lateral anastomosis, incising the duct as well as the

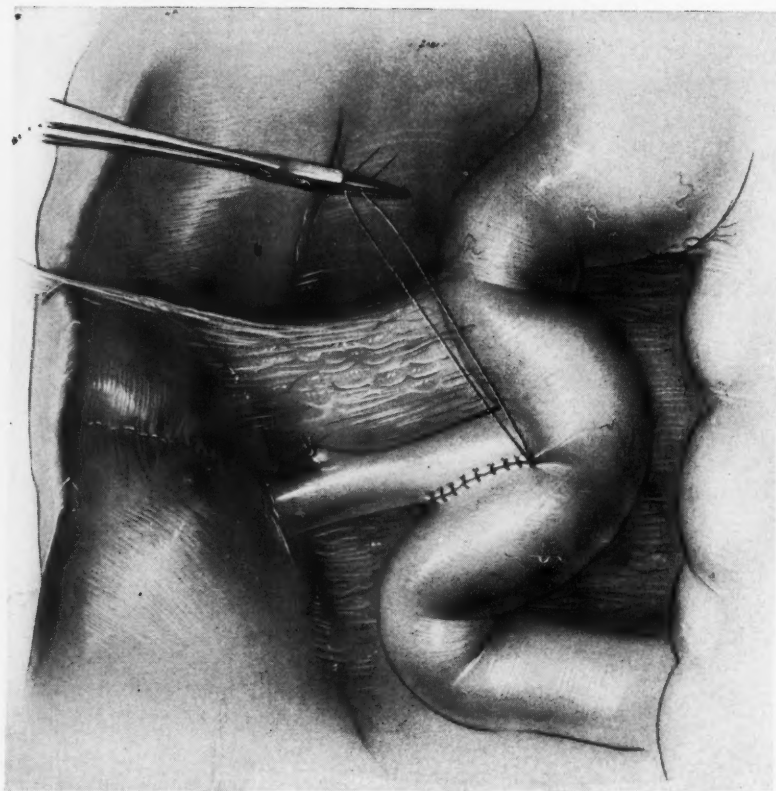


FIG. 4.—The anastomosis is completed; as a rule, the opening will admit the tip of the little finger. The anterior and posterior mucosal sutures are made with No. 000 catgut, while the interrupted serosal sutures are of fine silk. The cystic duct has been ligated and divided, the gallbladder removed and the liver notch sutured. Penrose drains are used following all these operations, but are not placed near the anastomosis line and are removed after 72 hours.

duodenum in the longitudinal direction. In the presence of injury or obstruction of the hepatic duct, if the remaining length above will not permit a lateral anastomosis, one will, of course, have to unite the end of the duct to the duodenum. In order to prevent leakage and to insure passage of the bile into the intestinal tract, we have placed several sutures in the duodenum and anchored it to the liver surface around the anastomosis. We performed this operation not long ago for a patient who had a fistula of the hepatic duct near

CHOLEDOCHODUODENOSTOMY

the liver surface, following cholecystectomy elsewhere. Below the fistula, the common duct was quite small and ended blindly, a large segment of it having been obliterated. The remaining duct was trimmed away, the duodenum was freed and the anastomosis consummated in the manner described. The patient's convalescence proceeded satisfactorily and, to the present time, she has had no further disturbance.

It has been observed that in cases of the foregoing type, wherein the duct is anastomosed near the liver hilus, the result is likely to be disappointing. Walters and Lewis⁴ reported 98 cases of duct stricture, in 34 of which choledochoduodenostomy was performed with good results in 28 cases, whereas hepaticoduodenostomy was performed in 31, with good results in only 13. Presumably, the poorer results following the higher anastomoses are attributable largely to cholangitis incident to ascending infection from the intestinal tract. This complication has been a matter of wide concern, the ultimate effect being the formation of liver abscesses and complete hepatic dysfunction, and numerous procedures have been devised to obviate such a contingency when the common duct has been destroyed. Among the more recent of these procedures is that suggested by Allen,¹ which directs the intestinal current away from the liver. By this method, the jejunum is divided, the distal end sutured over a catheter to the end of the hepatic duct in the liver sulcus and anchored to the surrounding liver surface. The proximal segment of the jejunum is united to the distal end at a lower level, after the method of Roux. The tube is brought out through an opening in the jejunum and a stab wound in the abdominal wall. A vent is made in the portion of the catheter which lies within the jejunum, to permit the passage of bile into the intestinal tract; thus, there is no likelihood of an external fistula while the catheter remains in place.

Cole,² and his associates, have presented a similar operation, with the same object in view. They employ a vitallium tube instead of a catheter and, as a further precaution against ascending infection, suggest the creation of valves in the arm of the jejunum which is attached to the duct. In their experience, this procedure has been more successful than direct anastomosis of the intestine to the duct.

We feel sure that both these operations are well worth while, though, to the present time, the few patients for whom we have performed hepaticoduodenostomy have exhibited no evidence of an ascending infection and cholangitis.

We have performed choledochoduodenostomy in 22 cases and hepaticoduodenostomy in three, a total of 25 cases. Nineteen of the 25 were for obstruction by stones, stricture or pancreatitis, or for injury of the ducts. Two were for carcinoma of the pancreas and two for carcinoma of the ducts, while in two cases we could not be sure whether the obstructing lesion was a cancer of the pancreas or a severe pancreatitis (Table I).

Ten, or 40 per cent, of the 25 patients had had a previous operation, and four of these had a biliary fistula. In three cases, both operations were performed by us. Two of these three were the cases previously described. The third was that of a man, age 73, who had cholecystitis with stones and perfora-

tion, and chronic pancreatitis. The gallbladder was removed and, as the duct was only slightly enlarged and contained no stones, a T-tube was merely inserted for drainage. The probe would not pass into the duodenum, presumably on account of the pancreatitis. His jaundice persisted, and at the second operation five months later, a stricture of the duct within the pancreas was found. The pancreatitis had completely subsided. The patient died of a pulmonary complication two days after the choledochoduodenostomy.

This was one of the two postoperative deaths in the entire group. The other occurred 18 years ago; the patient had a choledochoduodenostomy, also for stricture of the common duct. The fatal outcome was apparently due to shock. These two cases constitute an operative mortality of eight per cent.

Seven patients have died since their dismissal from the hospital. Four of the seven had malignancies and succumbed to the effects of the disease. Three had benign lesions, but died months or year later of other causes. Of the remaining 16, 13 had a choledochoduodenostomy for benign obstruction of the common duct. All of the 13 have remained entirely well, not one having had any disturbance indicating an ascending infection or further obstruction (Table II).

TABLE I
TYPES OF LESIONS AND MORTALITY IN 25 CASES OF
CHOLEDOCHODUODENOSTOMY AND HEPATICODUODENOSTOMY

	Cases	Mortality
Carcinoma pancreas.....	2	0
Carcinoma ducts.....	2	0
Carcinoma pancreas or pancreatitis?.....	2	2
Benign obstructive lesions.....	19	2 (15%)
Totals.....	25	2 (8%)

TABLE II
RESULTS IN 25 CASES OF CHOLEDOCHODUODENOSTOMY AND HEPATICODUODENOSTOMY

	Patients	Died Post-operatively	Died Subsequently	Living and Well
Choledochoduodenostomy.....	22	2 (11%)	7	13 (60%)
Hepaticoduodenostomy.....	3	0	1	2 (66.6%)
Totals.....	25	2 (8%)	8	15 (60%)

COMMENT.—From the study of this group of cases, two points are outstanding: First, the necessity for the use of every precaution in operations involving the gallbladder and ducts. The fact that in five, or 20 per cent, of the 25 cases the common duct had been damaged in a previous operation is impressive evidence of the need for wide exposure with definite identification of the vessels and ducts, and meticulous care in the use of clamps, the placement of ligatures, and in otherwise handling the tissues.

The point which we wish to make above all others, however, is that choledochoduodenostomy with the lateral anastomosis is decidedly the operation of choice when the duct is distended and the distal end is partially or wholly strictured or may become so, or is obstructed by a mass. In such cases, choledochostomy, even with dilatation of the duodenal outlet of the duct, is likely to be

inadequate; bile stasis may recur and the duct again become distended, necessitating choledochoduodenostomy as a secondary operation. On the other hand, immediate anastomosis will prevent too rapid decompression of the ducts, will provide ample drainage, and will give every assurance against further obstruction of the flow of bile. In these respects, choledochoduodenostomy is not only a more conservative operation than cholecystostomy, but may frequently prove a lifesaving procedure.

REFERENCES

- 1 Allen, Arthur W.: A Method of Reestablishing Continuity between the Bile Ducts and the Gastrointestinal Tract. *Trans. Southern Surg. Assn.*, **56**, 28, 1944.
- 2 Cole, Warren H., Ireneus, Carl, Jr., and Reynolds, John T.: The Use of Vitallium Tubes in Strictures and Absence of the Common Bile Duct. *ANNALS OF SURGERY*, **122**, 490, October, 1945.
- 3 Ravdin, I. S., and Frazier, W. D.: The Advantages of Gradual Decompression following Complete Common Duct Obstruction. *Surg., Gynec., and Obst.*, **65**, 11, 1937.
- 4 Walters, Waltman, and Lewis, Everett B.: Strictures of the Common and Hepatic Bile Ducts: A Report of 98 Cases. *Lahey Birthday Volume*, p. 443. Charles C. Thomas, Baltimore, 1940.

DR. ARTHUR W. ALLEN, Boston, Mass.: Doctor Sanders' very interesting paper gives me an opportunity to make a report of progress on our preliminary work on restoration of continuity between the biliary system and the intestinal tract, which I presented to this Association a year ago. At that time I had operated upon eight of these patients with these concepts. We felt it was fairly important to do this anastomosis in an isoperistaltic manner to prevent ascending infection. Perhaps that concept is wrong in that, when dealing with normal or comparatively normal structures, the opening may very well stay patent and the patient may not develop ascending infection. I am beginning to believe that many cases of recurrent chills and fever which occur are not all based on ascending infection, but are due to stricture at the point of anastomosis. Still I think this method of reconstruction is an easy and simple one and has some features that are valuable.

Since my original report I have had six additional cases and have learned a trick or two. I have the feeling that one should attempt to keep the anastomosis open for a long time, particularly in scar tissue, which is bound to exist in this locality. Perhaps Doctor Cole's method with the vitallium tube may be superior, but our experience has been so unhappy with this type of tube that I feel it should be replaced by other methods. We have also the experience of not having a rubber tube pass spontaneously. I have had to do two operations upon one patient because the tube did not stay in place long enough. It is difficult to determine how to fix the tube so it will stay. The best method we have been able to devise is by interrupted cotton sutures.

I believe the tube should be left in place for three months, so that fairly normal continuity may be established. If one could accomplish this I believe these patients will not have episodes of chills and fever. One is not likely to have this trouble when dealing with a large duct. The tube does not have to stay as long under these circumstances as in the cases with scar tissue from traumatic injuries high in the hepatic duct. It should be borne in mind that careful end-to-end suture is the method of choice where the lower segment of the duct is present and not fibrosed.

DR. FRANK H. LAHEY, Boston, Mass.: So much has been said in this discussion about strictures of the duct that I would like to say a word about vitallium tubes on the basis of our experience with them, lest you put too much faith in them, as I am sure we have. I feel very strongly that our conception of the value of vitallium tubes in strictures of the common bile duct was on a wrong basis. We thought of this in terms of how well the tissues will tolerate vitallium tubes when, as a matter of fact, the all important thing is, does a vitallium tube become blocked just as frequently or less frequently than does a rubber tube? In our experience, vitallium tubes become blocked

with inspissated bile just as often as do rubber tubes and, therefore, as a method of obtaining flow through the tube have no advantage whatever over rubber tubes and, due to their rigidity and inflexibility, have many disadvantages. Rubber tubes have the very desirable quality of being able to adjust themselves through the tortuous channels often present in strictures of the duct, through which the tube must pass and adjust itself without pressure. They have the additional advantage of not producing pressure necrosis that will and has in certain cases resulted from the use of the rigid vitallium tube.

We have just had a patient die at the end of ten years in whom a rubber tube completely replaced a section of his hepatic and common ducts at least three inches long, as a result of an operation elsewhere. During this ten-year period he has had no jaundice, and has been completely free from any obstructive symptoms. An autopsy was obtained and the tube was found to have been completely blocked by bile, demonstrating that the flow of bile, at least over a large portion of this ten-year period, had been not through the tube but about the tube. This brings the question up in my mind as to whether or not I have not been wrong in my desire to put in tubes of the largest possible caliber. I am not certain that we should not, in some of these cases, put in smaller ones with the hope that when they become blocked they will maintain patency and permit the flow of bile about the tube.

In an experience now in which we have operated upon 144 patients for strictures of the common and hepatic ducts, we have arrived at certain quite definite convictions. One is, and I feel very positive about this, that if there is a complete loss of substance of the duct and a tubing of any character is put in to replace this, it can never be removed without the later occurrence of a stricture. We have seen this occur now a sufficient number of times so that I feel convinced of the soundness of this observation.

We have learned, in this large experience, that there are few cases of stricture of the bile ducts in which, with good mobilization of the duodenum and division of that portion of the pancreas through which the lower end of the common duct runs, the lower end of the common duct cannot be found and, with its mobilization and the mobilization of the duodenum, its end brought up very close to the injured or severed end of the hepatic duct for anastomosis, provided that injury is not within the hilum of the liver, where it often is.

Having established the conviction that in the presence of a definite scar stricture of the duct, a permanently indwelling tube must be inserted, and having determined that vitallium tubes have no advantage over rubber, we have in two cases made use of the molded bouncing clay devised by the General Electric Company of Schenectady as a substitute for rubber. It can be molded into any shape and caliber, with a ridge about its center to prevent its being passed; it probably has no advantage whatever over rubber or vitallium tubes in its likelihood of being blocked by inspissated bile, but it does have the very great advantage that it can be molded into any shape desired and is elastic and flexible.

I wish to speak of one more lesion with which we have had experience that relates itself to this discussion, and that is the recurring common duct stone dependent upon bile stasis, and dilatation of the common and hepatic ducts due to an inadequate outlet at the sphincter of Oddi, which in these cases has become fibrosed.

We have now operated upon several of these patients in whom the recurrence of common duct stone has brought them into our hands. We have succeeded in managing these cases so that there has been no recurrence of the common duct stone by opening the duodenum, splitting the fibrosed sphincter, doing a plastic operation on the sphincter, introducing a T-tube, with one end long, into the common duct so that its lower end projects into the duodenum through the reconstructed sphincter, leaving it in for a year to 14 months until the new opening has become healed and molded. This results in adequate drainage of the distended duct, overcomes bile stasis and precipitation of its crystalline elements, as occurs when the sphincter is constricted and fibrosed, and the prevention of the recurrence of common duct stone. I have only one warning to make in connection with this operation and that is, as you introduce the T-tube into the common duct, to suture it tightly before the duodenum is opened, and demonstrate by a probe the point of entrance of the common duct and sphincter before the incision in the duodenum is made. If this is not done, one will often be surprised at what a low point in the duodenum the common duct enters as water is injected into the T-tube and squirts out at the sphincter to locate the point of entrance of the duct.

CHOLEDOCHODUODENOSTOMY

DR. ALBERT O. SINGLETON, Galveston, Texas: I am glad to have had the opportunity to hear the experiences of those who have had a large experience in the reconstruction of common bile ducts. When one has had the problem of trying to repair an injured duct it makes him extremely careful never to be responsible for this injury himself. So far as I am able to tell, the results generally of any method of reconstruction are not too flattering. Stricturing is the greatest obstacle to success. Some of our patients have gone several years without developing a stricture but eventually jaundice has occurred with toxic symptoms indicating an obstruction. Whether the infection is due entirely to the retrograde spread or whether it is due to the stricturing I am unable to say. I am inclined to believe that without stricturing infection is not a great obstacle to a permanent good result. Our experience with vitallium tubes has been disappointing. As long as the tubes have been in place (and we have used six of them) the patients have done very well, but invariably within a year or two the symptoms recur and roentgenograms have shown that the tube has passed into the intestine. We should not overlook an opportunity to spread a campaign against the untrained attempting to do gallbladder surgery and, furthermore, no one should attempt to do surgery in this region without excellent exposure and meticulous care to avoid accidents to the duct.

DR. WARREN COLE, Chicago, Ill.: I have always known that Doctor Sanders was a brilliant surgeon and a fine orator, but I did not know he was also lucky. He has had a series in which the common duct was unusually large and could be mobilized well; moreover, he has had very few cases of cholangitis of the suppurative type. However, most of this good fortune is, no doubt, well deserved because of good judgment and skillful technic. We have had a relatively large number of patients with suppurative cholangitis; three or four of these had a carcinoma of the pancreas, a lesion in which suppurative cholangitis is not supposed to develop.

The actual cause of suppurative cholangitis is not known, but I agree with Doctor Allen that stricture is a very important factor. I believe also that regurgitation of food has a lot to do with its development when the sphincter of Oddi is not present. We proved this to our own satisfaction by trying certain types of operations. Doctor Sanders showed slides of the two types we have used. When we anastomosed the hilar duct at the liver to a loop of jejunum we got regurgitation of food, and cholangitis in almost every case. In three of these patients we simply interrupted the proximal arm of the loop and made folds or valves in the distal loop. This procedure promptly stopped the chills and fever.

Doctor Sanders' method of not completely severing the duct preserves the sphincter of Oddi so that it can function in case the terminal end of the duct should open up later. If you have obstruction due to inflammatory pancreatitis, this type of operation is particularly adaptable, since the obstruction will usually disappear later with subsidence of the inflammation. I am convinced that this procedure is better than anastomosing the gallbladder to the jejunum or duodenum. I have had poor results with cholecystenterostomy because of stenosis of the stoma; I believe the only reason we do not see more failures is because the operation is usually performed for inoperable carcinoma of the pancreas, and the patients die before we have a chance to see whether or not the stoma will remain open longer than a few months. I have had two cases in which the cholecystenterostomy stoma became stenosed on three occasions. These three operations were performed by three different members of the Chicago Surgical Society and were supposedly done well.

In summarizing my ideas on the anastomosis of the hilar duct to the jejunum (when no remnant of the common duct is found), I am convinced we should anastomose the hilar duct to an arm of jejunum after the Roux principle as popularized by Doctor Whipple. We have not had any instances of obstruction of the vitallium tube, although we admit we may have been lucky. I am not yet convinced that vitallium tubes must stay in position permanently, but I do believe that they should be kept in place for several weeks, at least until the fibrosing process stops; then, if the tube drops out, we have a good prospect of having an opening which is large enough to maintain function without stenosing.

DR. R. L. SANDERS, Memphis, Tenn. (closing): I wish to thank Doctors Allen, Cole and Lahey for their generous discussion of my paper.

It is interesting to know of Doctor Allen's additional experience with the ingenious operation which he described before this Association last year. His success in 14 cases certainly justifies further trial of the method when reconstruction of the injured duct is indicated.

Doctor Cole referred to my good luck in the cases reported. I am not sure that the results have been due to good luck. In the presence of an abnormally large common duct, a side-to-side anastomosis to the duodenum is a more physiologic operation than an end-to-side anastomosis. By making the stoma sufficiently wide, one may expect it to remain patent, and the bile to pass freely and continuously into the intestinal tract. Because of the equalization of pressure between the biliary and intestinal tracts, ascending infection should not be a serious consideration. Thus far, none of our patients have exhibited any clinical evidence of ascending infection.

In regard to Doctor Lahey's discussion, I am not at all in accord with his idea of making an easy operation difficult. Moreover, to do any plastic operation on the lower end of the common duct, particularly with the use of the transduodenal approach, is to invite trouble. This is especially true of those cases wherein an extensive pancreatitis, with edema and induration of the tissues, is associated. The operation I have described is really a short-circuiting procedure, similar in principle to gastro-enterostomy for obstruction of the pylorus, the distal portion of the duct being undisturbed as it passes through the pancreas. The technic is simple and readily executed, and the danger of opening inflamed areas is obviated. Also, the likelihood of further obstruction from the reformation of stones is negligible. If Doctor Lahey will try this method, making a simple lateral anastomosis with a very large stoma, I am sure he will appreciate its merits.

MALIGNANT TUMORS OF THE SMALL BOWEL*

J. M. EMMETT, M.D., AND M. L. DREYFUSS, M.D.

CLIFTON FORGE, VA.

CARCINOMA OF THE SMALL BOWEL is quite rare. Dougal states that not over 300 cases have been reported. One may be sure, however, that a large number of sporadic cases—and most surgeons will only have isolated experiences with this condition—have remained unpublished. This is regrettable because the diagnostic and therapeutic management of carcinoma of the small bowel must be considered utterly unsatisfactory and only by applying cumulative knowledge may one expect an improvement in this situation. It is for this reason that we feel justified in reporting two cases of carcinoma of the small bowel, one of them typical, the other, peculiarly interesting because of the occurrence within 2.5 years of two separated malignant lesions of the intestinal tract.

CASE REPORTS

Case 1.—Mrs. E. R., white, age 33, was admitted to the Chesapeake and Ohio Hospital, May 23, 1945, with the following history: Her mother had died of cancer of the stomach. Her past history was not contributory. She had had no children, but had had one miscarriage. An appendectomy had been performed in 1932 for acute appendicitis. Her present complaints dated back about six months. During that time she had experienced gradually increasing gaseous distress, gurgling and rumbling in the area of the stomach and upper abdomen. During the three weeks before admission she had nausea and vomiting after the noon and evening meal, but not after breakfast. She noticed considerable distention in her epigastric region immediately following meals. The vomitus was described as being bitter and containing particles of food. It usually occurred one or two hours after eating, and she felt very relieved of her distress after she had vomited. She had lost about eight pounds of weight. Physical examination was negative. Gastric analysis showed normal values. Hemoglobin was 84 per cent. The red count was 4,360,000. The white count was 5,850. A diagnosis of partial intestinal obstruction was made. Gastro-intestinal roentgenologic series showed a normal esophagus and stomach except for marked pylorospasm. The entire duodenum was dilated, but no defects were noted. After two hours there was considerable gastric retention and the duodenum was still distended. The same findings persisted for a five-hour period. The dilated duodenal section ended abruptly at the duodenojejunal junction.

Operative Procedure.—May 26, 1945: The abdomen was opened through a high, left, paramedian incision. An annular constricting lesion was found at the duodenojejunal junction. A circular ulcerated carcinoma was present at this site. The entire thickness of the wall was made up by tumor. Many small mesenteric nodes were found in the jejunal mesentery. The complete segment of involved jejunum, with a cuff of normal bowel four inches way from the lesion on either side, along with the mesentery, was resected and an end-to-end anastomosis was established. The wound was closed anatomically.

Microscopically, the tumor was a highly differentiated papillary adenocarcinoma destroying the intestinal wall and metastasizing to the majority of the dissected lymph nodes was present. There was also Lymphadenitis, obviously secondary to the ulceration of the mucosa.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

The patient made an uneventful recovery, and was discharged from the hospital on June 8, 1945. This patient was seen within the past ten days and is apparently in excellent condition, without symptoms. However, it is realized that optimism as to a permanent cure is not warranted.*

Case 2.—W. V., a 66-year-old white male, had been suffering with intermittent constipation and diarrhea and various digestive disturbances for two years. When first seen, in May, 1942, he had been sick for two weeks with pain around the umbilicus, nausea



FIG. 1.—Case 1: Roentgenogram showing obstruction at duodenojejunal junction and dilatation of duodenum.

and vomiting. His bowels were moving three or four times a day, but only a very small amount of stool which contained blood was passed each time. He stated that similar episodes had occurred almost every year during the past 15 years. Two years prior to the time that he was seen, his habitual constipation gave way to moderate diarrhea, which lasted for about a year. Later his constipation recurred. He had lost appreciable weight.

Physical examination was essentially negative, except for a moderate intestinal distention and tympanism of his abdomen. No masses were felt. A presumptive diagnosis of low intestinal obstruction, due probably to a tumor, was made. Roentgenologic studies of his lower intestinal tract, with the use of barium enemas, proved very difficult and unsatisfactory because of a very marked atonia of the bowel. The roentgenologist felt that he could not arrive at a positive conclusion, but he thought that here was a partially obstructing lesion at the midportion of the sigmoid. Proctoscopic examinations were negative for tumor. Laboratory studies were not helpful. Red and white blood counts were normal.

* On Jan. 8, 1946, the patient was operated on for a massive pelvic tumor. Both ovaries were tremendously enlarged. Metastatic adenocarcinoma with marked proliferation of stroma was found.

Fig. 4



Fig. 5



Fig. 2



Fig. 3

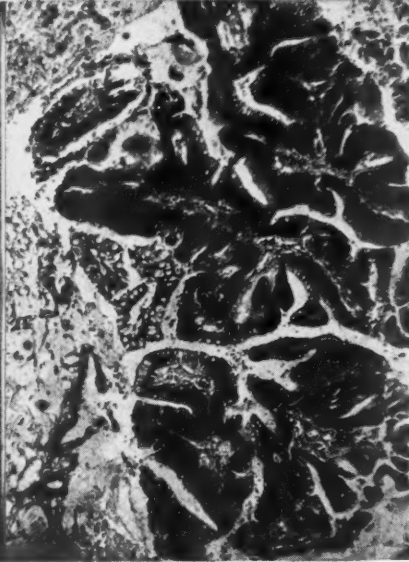


FIG. 2.—Case 1: Operative specimen with stenosing circular carcinoma.
FIG. 3.—Case 1: Microscopic appearance of tumor in intestinal wall.
FIG. 4.—Case 1: Metastatic tumor in regional lymphnode.
FIG. 5.—Case 2: Microscopic appearance of primary tumor of sigmoid.

Operative Procedure.—June 6, 1942: The abdomen was explored and a constricting neoplastic lesion of the upper sigmoid was found. An abdomino-perineal resection, after the method of Myles, was performed. The resected specimen was 32 cm. long, contained a cauliflower type of tumor, beginning 16 cm. above the anus and involving the sigmoid for a distance of 6 cm. The serosa was not grossly involved. The sigmoid was found to be adherent to a loop of small intestine. The tumor proved to be a typical adenocarcinoma of the large bowel which involved the muscular layer, but did not infiltrate the serosa.

The patient made a satisfactory recovery, and was discharged from the hospital 18 days later.

He was readmitted, in March, 1945, approximately three years later. He had been doing well until two months previously, when he began to vomit after meals. This vomiting became more exaggerated and his abdomen became distended. The colostomy began to need frequent irrigations and the stool specimens became liquid and scanty and contained some blood. The vomitus contained usually food just eaten. He had lost weight rapidly.

Physical Examination.—The patient was poorly nourished and greatly dehydrated. The abdomen was distended. No masses were felt. He had a mild anemia of 67 per cent hemoglobin, 3,950,000 red cells. The clinical diagnosis was partial intestinal obstruction, probably due to extension of the malignant lesion of the sigmoid. Gastro-intestinal roentgenologic series showed only a marked gastric stasis. After two hours the barium was still in the stomach. An 18-hour film was made after the patient had vomited a large amount of barium, and showed distended coils of small bowel. The roentgenologic diagnosis was not helpful, although the roentgenologist felt that the patient had an obstructive lesion of the small bowel.

Operative Procedure.—March 11, 1945: The patient was explored and an obstructing, constricting neoplasm was observed in the distal ileum just proximal to the ileocecal valve. It was relatively easy to resect the distal ileum, the cecum, and ascending colon. An ileocolostomy was established.

The patient made a very satisfactory operative recovery, and was discharged from the hospital on March 20, 1945. He died six months later at home.

Pathologic Report: The specimen consisted of 20 cm. of small bowel, cecum, appendix and initial portion of the ascending colon. A round, firm tumor mass, 5 cm. in diameter, was found in the ileum, only a short distance from the ileocecal junction. Corresponding to it, there was a circular, stenosing ulceration. The wall in this area was 3 cm. thick, firm, and the muscle was replaced by a mottled greyish and yellowish tissue. The serosa was slightly opaque. On microscopic examination, the mucosa and the muscularis were destroyed by an adenocarcinoma, with some tendency to formation of papillae. There was hardly any evidence of secretion on the part of the tumor epithelium. There was much necrosis and the muscularis was extensively and deeply invaded.

Comparison of the histologic features showed, beyond the different localization of the second tumor, that this patient had two primary tumors of the intestinal canal—the first one of the sigmoid, the second of the ileum.

DISCUSSION.—In estimating the incidence of carcinoma of the small bowel it must be kept in mind that the older statistics, based on large numbers of autopsies, include in the neoplasms of the small bowel malignant lesions other than carcinoma, such as sarcoma and carcinoid, and are, therefore, not accurate. Ewing estimates that 3 per cent of the carcinomas of the gastro-intestinal tract—from the cardia to the anus—are located in the small intestine, and this figure can be considered as representative. In comparison, 60.7 per cent of all gastro-intestinal sarcomas occur in the small bowel (Shallow). There is some discrepancy among the various authors regarding the distribu-

tion of carcinoma in the three main divisions of the small intestine, which is not surprising since most series are quite small and none reaches 100 cases. Slightly less than one-half of the carcinomas occur in the duodenum, but this figure would include tumors of the papilla of Vater. Ileum and jejunum are about equally involved by malignant neoplasms in general, but sarcoma, as well as carcinoid tumors, are considerably more frequent in the ileum and carcinoma correspondingly more rare.

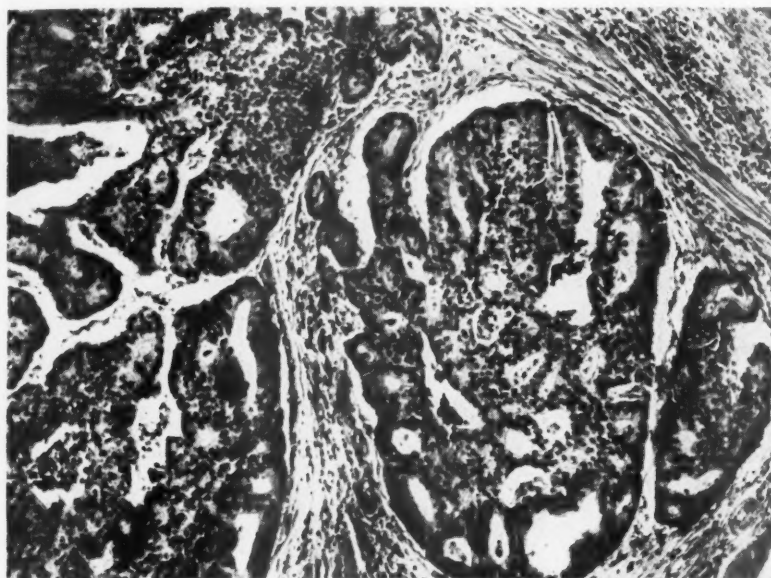


FIG. 6.—Case 2: Microscopic appearance of primary tumor of jejunum.

There is no satisfactory explanation for the relative infrequency of carcinoma in the small intestine. The alkaline reaction and liquid consistency of its contents have been mentioned as being possibly responsible, as have the absence of sharp bends and abrupt transitions of one type of epithelial lining to another. However, all this must be considered sheer speculation.

As to their gross appearance, one can distinguish an infiltrative and a fungating type. The former is more apt to produce a napkin ring type of stenosis; the latter tends more to ulceration and occasionally to intussusception. However, as a rule, malignant lesions show much less tendency to intussusception than benign tumors, such as lipomas or myomas. Microscopically, they are all adenocarcinomas, with some variations in the details of their pattern.

It is remarkable how early carcinoma of the small intestine metastasizes, or rather, in how many cases metastases are present when the primary tumor is discovered. In Shallow's series, 31 of 38 cases showed metastases or extension. The metastases occur into the regional lymph nodes, the liver, pancreas, retroperitoneal lymphnodes, lungs and bones, in this order.

In about 80 per cent of all cases a quite typical history can be obtained. Cramps, epigastric distress, bloating, rumbling, and short, recurring episodes of obstruction are the principal symptoms. Occult blood and moderate anemia may be present. Shallow found a palpable mass in 75 per cent of his cases—which is truly remarkable. The average duration of symptoms is about six months. Only occasionally is the onset dramatic, with perforation, massive hemorrhage or acute obstruction.

The most important single diagnostic method is the roentgenologic examination of the small bowel. This is difficult procedure, even in the most experienced hands, as evidenced by Shallow's statement that in only one-half of his cases examined roentgenologically could the lesion be demonstrated. In this connection, it should be borne in mind the just-mentioned fact that the same author could palpate a tumor in 75 per cent of his cases.

The almost ordinary presence of metastases makes extensive surgery necessary in most cases. This, and the generally poor condition of the patients, with a long-standing malignant lesion in the absorbing portion of the intestines, accounts for the almost incredibly high operative mortality of 44 per cent. The mortality is even higher for the duodenum, but somewhat lower for the ileum. Nevertheless, resection, with anastomosis, is indicated even in the presence of metastases because of the temporary relief from an ulcerated, bleeding lesion and obstruction. Postoperative radiation has apparently not shown any remarkable results. It is being used, though, in view of the poor results obtained with surgery alone. It is estimated that not more than 5 per cent of patients with carcinoma of the small intestine survive the five-year period.

Since the technic of intestinal resection is highly perfected, the main effort of improving the deplorably poor therapeutic results must be directed toward early diagnosis and optimal preoperative preparation. While much progress has been made in the latter respect in recent years, one cannot be optimistic as to earlier diagnosis, with the present diagnostic methods. Until better means are found, we must rely on our clinical skill, based on personal and common experience. With this consideration in mind, this report has been presented.

REFERENCES

- Puppel, D. S., and Morris, L. E., Jr.: Adenocarcinoma of the Ileum in a Girl, Age Thirteen. *Amer. J. Surg.*, **64**, 113-115, October, 1944.
- McDougal, Wm. J.: Carcinoma of the Small Intestine. *Amer. J. Surg.*, **64**, 119-122, October, 1944.
- Shallow, Th. A., Eger, Sh. A., and Carty, J. B.: Primary Malignant Disease of the Small Intestine. *Amer. J. Surg.*, **69**, 372-383, September, 1945.
- O'Donoghue, J. B., Lichtenstein, M. E., and Jacobs, M. B.: Primary Adenocarcinoma of the Jejunum with Intussusception. *Amer. J. Surg.*, **63**, 382-387, March, 1944.
- Howard, J. W.: Carcinoma of the Duodenum. *Amer. J. Med. Sci.*, **206**, 735-746, December, 1943.
- Boman, P. G.: Primary Carcinoma of the Jejunum and Ileum. *Amer. J. Med. Sci.*, **207**, 779-788, May, 1944.

MALIGNANT TUMORS OF SMALL BOWEL

- Flynn, James M.: Adenocarcinoma of the Ileum. *Amer. J. Roent. Res.*, **48**, 163-166, August, 1942.
- Mayo, Chas. W., and Nattrour, W. S.: Carcinoma of the Jejunum. *S. G. and O.*, **65**, 309, 1937.
- Rankin, F. W., and Newell, C. E.: Benign Tumors of the Small Intestine. *S. G. and O.*, **57**, 501-507, 1933.

DISCUSSION.—DR. G. V. BRINDLEY, Temple, Texas: This is an excellent paper upon a very important subject. I should like to emphasize a few facts brought out in the paper.

It is true that the tumors of the small bowel are diagnosed late, and this is probably a most important factor contributing to the poor prognosis of these lesions. The tumors are usually not demonstrated by routine roentgenologic studies of the gastrointestinal tract, but to diagnose such neoplasms a special small bowel study is required.

In the ten-year period between 1935 and 1944 there were seen in the Scott and White Clinic 17 patients with tumors of the small bowel; 11 of these were carcinoma and six were sarcoma. A majority of these patients had rather advanced lesions when first seen, as were the cases reported by the essayist. The predominating symptoms in most instances were those of variable degrees of obstruction. However, one case with a carcinoma of the jejunum was admitted shortly after a profuse intestinal hemorrhage, necessitating several transfusions.

RESTORATION OF CONTINUITY AFTER RESECTION OF THE RECTUM*

HOWARD MAHORNER, M.D.

NEW ORLEANS, LA.

THE FIRST CONCERTED ATTEMPTS to remove cancer bearing areas of the rectum at the end of the last century were unsatisfactory, having a large mortality and morbidity and a high percentage of recurrence. In 1907, Miles deserted the Kraske type of posterior resection with anastomosis or sacral anus in favor of combined abdominoperineal resection and so popularized the latter procedure that it became the most widely employed for removal of cancer of the rectum. Lockhart-Mummery, in 1914, first performed the type of resection known by his name, which consists of preliminary colostomy and subsequent posterior resection of the rectum. These two operations have been popular during this century, and in recent years abdominoperineal resection in its original or modified form was undoubtedly the first choice of most surgeons.

During all this time, the thought of colostomy has continued to be abhorrent to patients and many doctors, though the salvage of over 40 per cent of the lives otherwise doomed by cancer of the rectum has been a recompense worth that burden. But even then, the realization that life alone is not enough has spurred thoughtful men to continue the technical search for some method of removing the cancer adequately wide to affect a high rate of cure and yet permit restoration of the normal course and control of intestinal evacuation. In the past, feeble attempts were made in this direction, but more recently arresting reports have been made by Dixon, Wangenstein and Babcock and Bacon. No one who does only abdominoperineal resection for cancer of the rectum and rectosigmoid can read these reports without at least some doubt arising as to the choice of an operation for these lesions.

The assay as to whether it may be correct to remove the cancer bearing rectum and restore continuity will depend on the results compared to abdominoperineal resection of the rectum. This will include mortality rates, five-year cures, and postoperative sphincter function. So far, only such series as those reported by Dixon, Babcock, Bacon, and Wangenstein in this country, are large enough to be helpful ultimately in determining these factors. The superior type of operation chosen for restoring function also will not be determined easily, since there are many possibilities and combinations. Dixon and Wangenstein prefer an abdominal resection and anastomosis while Babcock and Bacon use a clever modification of the Hockenegg operation, undoubtedly more radical for the lower growths. Mandl, after a study of 1,000 cases from Hockenegg's Clinic, indicated his belief that sphincter preservation does not

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

RESECTION OF THE RECTUM

increase the incidence of recurrence of carcinoma. He prefers the Hockenegg pull-through operation which he had performed in the last 17 of 54 radical resections. His other resections were done by the Miles procedure. However in his cases, he reported the use of pull-through operations for lesions as high as 16 and 18 centimeters up from the anal outlet. Anterior resection with

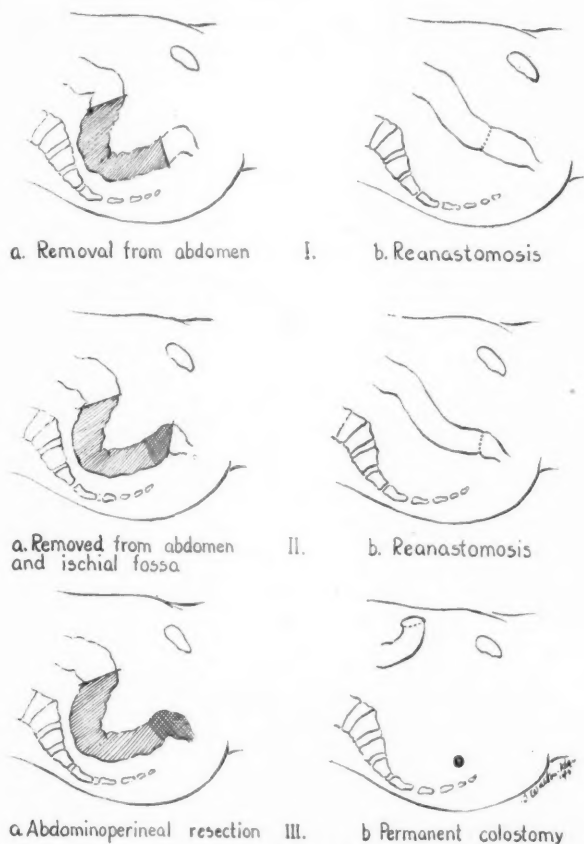


FIG. 1.—Three plans of resection for rectal carcinoma. Lesions in the rectum at least eight centimeters from the anal outlet may be removed and continuity reestablished transabdominally. Lesions extending below that level may be removed by abdominoperineal resection with abdominal colostomy or in certain cases by a combined anterior and posterior resection and anastomosis.

anastomosis would be easy in such high growths and I believe that for lesions at that level, both Hockenegg pull-through procedure and abdominoperineal resection will be replaced in popularity in the near future by the anterior resection and anastomosis.

The last 20 resections of the rectum or rectosigmoid on my private services have been done in one stage without preliminary colostomy. In 13 patients, attempts were made to reestablish normal positional continuity of the

bowel, *i.e.*, after resection of the rectum for carcinoma, an anastomosis was made by one of several means and in one instance, after complete resection of the rectum, the sigmoid was replaced through the sphincter. The effort to reestablish continuity failed in three patients though they recovered with a permanent colostomy. There were two deaths in the 20 resections. One fol-



FIG. 2.—Attachment of the sigmoid to the rectum after mobilization of the rectum for removal of a growth partially below the peritoneal reflexion. Lesions at this level can be brought up surprisingly high when all attachments of the rectum are freed down to the levator ani muscles.

lowed abdominoperineal resection of the rectum in one stage and another death followed transabdominal resection and anastomosis.

Transabdominal resection of the rectum was done according to a technic, essentially that described by Dixon. After exposing the abdomen through a midline incision, the peritoneum on each side of the mesosigmoid is cut. This incision is extended down into the pelvis on either side of the rectum. The incision in the peritoneum extends anterior to the rectum in the rectovesical or recto-uterine pouch. The superior hemorrhoidal vessels are identified and are transected and ligated at the promontory of the sacrum. Then the hand separated the two severed portions of the peritoneum and posterior to the hemorrhoidal vessels separates the rectum and retrorectal tissue from the hollow of

RESECTION OF THE RECTUM

the sacrum, down to the coccyx. The lateral and anterior attachments of the rectum are severed as far down as the rectal attachments of the levator ani muscles. The lateral ligaments of the rectum are cut. The rectum then may be drawn out and up amazingly high so that the growth-bearing segment then may be delivered even outside the abdominal wound. I prefer, after attaching the sigmoid to the rectum sufficiently far below the growth, to apply a Furniss



FIG. 3.—Aseptic anastomosis of the sigmoid and rectum with a Furniss clamp. If the remaining rectal segment is too short, a Parker-Kerr anastomosis may be accomplished.

clamp and remove the growth-bearing loop; or should the use of the Furniss clamp be unhandy because of a compromised space, I have chosen a Parker-Kerr technic for the anastomosis. I have not done an open anastomosis, though I realize this method has been used with a satisfactorily low mortality by Dixon, and others.

I usually do not make a complimentary colostomy but prefer a catheter

enterostomy in the sigmoid proximal to the anastomosis. The sigmoid is sutured to the parietal peritoneum near the emergence of the catheter which is brought through a stab wound in the abdominal wall. Colostomy may be an advantage however in poorly prepared or partially obstructed colons.

In this operation, with reestablishment of continuity, rectosigmoid growths and rectal growths down to the lowest part of the rectum can be removed with

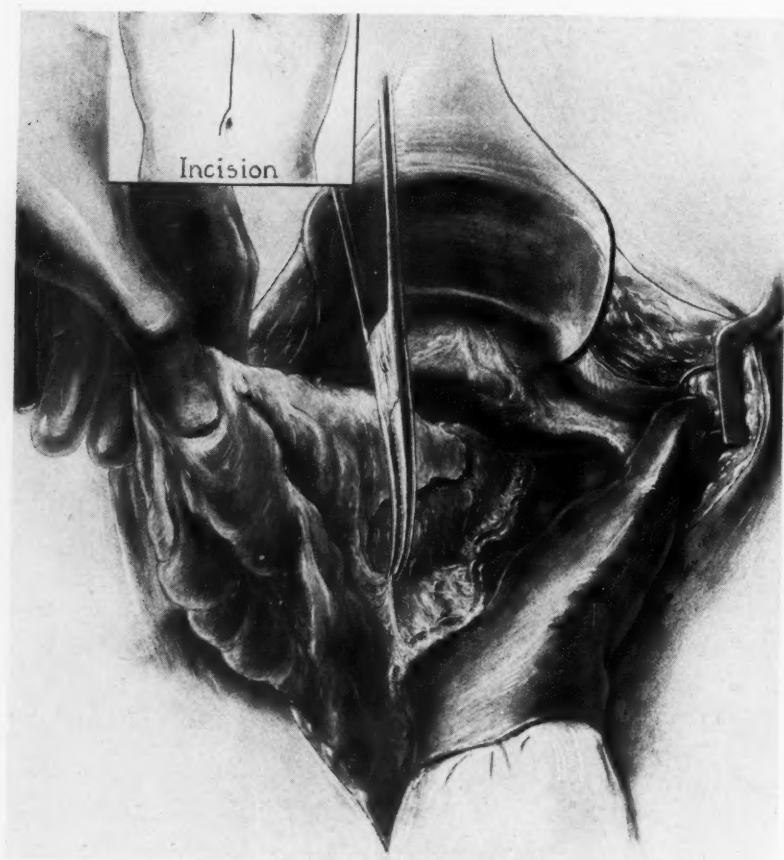


FIG. 4.—Mobilization of the rectum in an abdomino-ischial resection of the rectum for extremely low rectal growths. The rectum may be freed without first ligating the superior hemorrhoidal artery. This is done to preserve better blood supply to the upper segment.

as much ablation of perirectal tissue and nodes as is accomplished in the Miles' abdominoperineal resection. But more tissue may be removed inferiorly and for the extremely low growths laterally in the Miles' type of operation. This probably has some bearing on the results for low rectal carcinoma and it probably has none for the high ones. The careful pathologic studies of Gilchrist and David, and Collier, Kay and MacIntyre, support the clinical impression that carcinomas of the rectum metastasize upward or laterally but not downward.

I have been able to remove a carcinoma by transecting the bowel three to four centimeters below the lowest gross extension of the growth and effect an anastomosis between the rectal stump and the sigmoid transabdominally when the lower end of the growth was no more than eight centimeters above the external sphincter, (external end of the anal canal) measured at proctoscopic examination before operation.

It is surprising how high up the rectum may be brought when it is mobilized in this operation. A growth at the peritoneal reflexion may be delivered up to the abdominal wall or even higher. This is due not only to elasticity of the rectum, but also in part to the curves of the normal rectum which, when loosened and rectified into a straight angle, add considerable length to an otherwise very short segment.

For those lesions whose lowest level is below eight centimeters above the anal outlet, it still may be feasible to remove the segment containing the growth and preserve the sphincter by one of several different procedures. Gaining in popularity is the Hocke-negg procedure which has been advocated in this country only by Bab-

cock and Bacon. Babcock, long an objector to abdominal colostomy, preferring even perineal colostomy, has described several methods of dealing with the lower stump in an abdominoanal proctectomy to reestablish continuity or normal position of the bowel with or without preservation of the sphincter. He deserves great credit for so long and so insistently championing the cause for normal continuity when few in this country adhered to his teaching.

I have attempted to reestablish normal continuity in five patients in whom the growth was too low to remove and perform anastomoses transabdominally. At least, part of each carcinoma was below eight centimeters above the external outlet of the anus, but the growth was still above the internal end of the anus. In the first three, the rectum was mobilized in the abdomen after ligation of the superior hemorrhoidal artery at the promontory of the sacrum. The abdominal wound was then closed and the patient turned. The rectum was delivered through a midline wound posteriorly, and the growth-bearing segment of the bowel removed and the sigmoid anastomosed to the stump of the rectum by interrupted sutures.

The rectum in all three of these sloughed, and it was necessary in the two who did not already have a complimentary colostomy to make one. All three

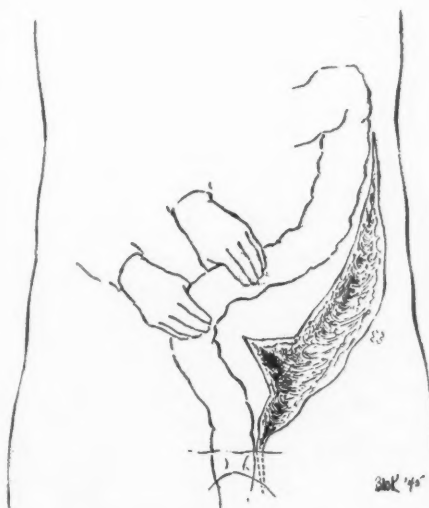


FIG. 5.—Incision into lateral peritoneal attachment to facilitate descent of the sigmoid into the pelvis for abdomino-ischial resection and anastomosis.

patients recovered but with permanent abdominal colostomies. In two patients since then, a successful anastomosis has been made from below by the following operation. The rectum was mobilized through a midline abdominal incision as

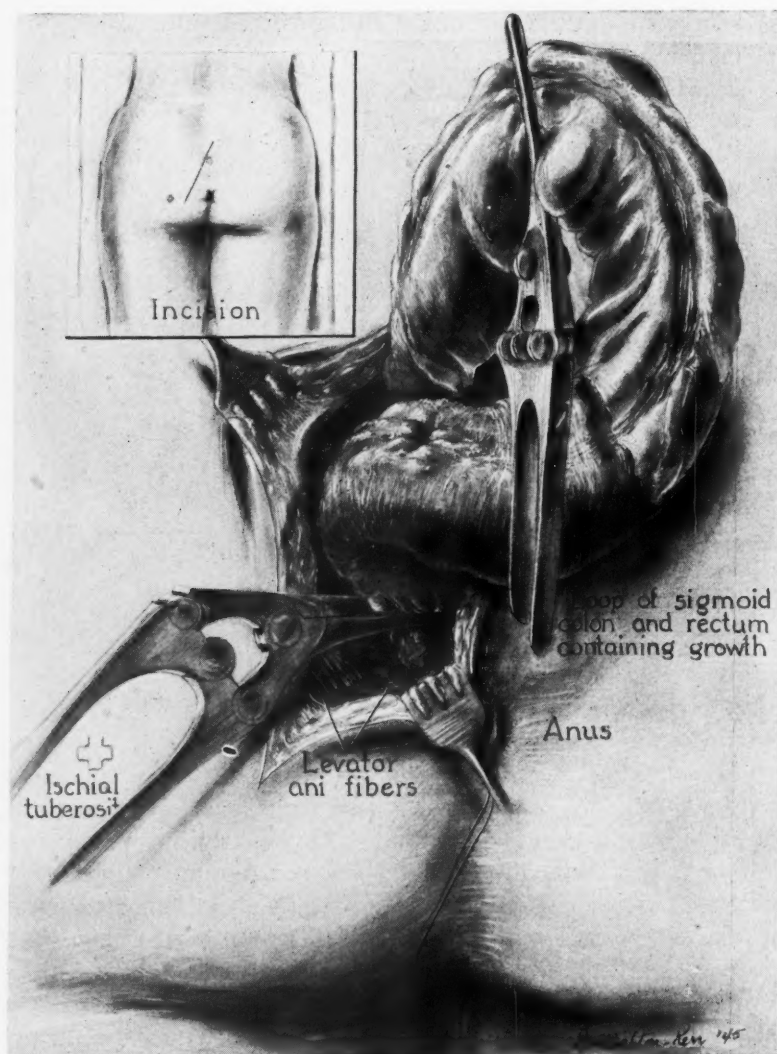


FIG. 6.—The ischial portion of an abdomino-ischial resection. An incision is made over the ischial fossa and is extended through the levator ani muscles on one side. The rectum is delivered and is removed leaving a stump only a few centimeters proximal to the anus. The superior hemorrhoidal artery is ligated high at a level which will not compromise blood supply to that area of the sigmoid which may be anastomosed without tension.

in the abdominoperineal resection. Exceptions, however, were made. The superior hemorrhoidal artery was not ligated at this stage. I found that it is perfectly feasible to mobilize the rectum from the sacrum when the superior

RESECTION OF THE RECTUM

hemorrhoidal artery is not ligated and without too much hemorrhage if the separation from the sacrum by the hand is carefully done, entirely posterior to the hemorrhoidal vessels. In addition to this, the sigmoid and the descending colon was mobilized by cutting the lateral peritoneal folds. Then crucial cutting of peritoneum in the mesosigmoid allowed more rectification of the sigmoid loop for its descent into the pelvis. The rectum and sigmoid were then pushed into the pelvis and the peritoneum released laterally was sutured over it, and around the sigmoid to form a new high pelvic floor. After the abdominal wall was closed, the patient was turned and an oblique incision was made from the tip of the sacrum in the midline downward and outward over the ischiorectal space and ending anterior to the anus and midway between the tuberosity of the ischium and the anus. The incision was deepened, cutting through para-anal fat and through the lavator ani. The coccyx was disarticulated and the presacral fascia incised. This permitted delivery of the already mobilized rectum. Farther dissection freed the rectum from the lavators and it was thus possible to transect this segment just above the anal canal. The sigmoid was then pulled well down to a level where it could be approximated to the remaining rectal stump without too much tension. Then only was the blood supply ligated and at that level. The anastomosis was made as an open anastomosis because the rectal stump was too short and the space too small to permit application of a clamp. Because they have been done recently, in neither of these cases has the complimentary colostomy yet been closed, though the immediate results have been encouraging enough to make me feel that further use of the method for certain low rectal growths is justified.

This plan of resection has the advantage that the abdominal portion of the resection removes the regional nodes, and the posterior part is done in a manner to result in little damage to sphincter mechanism. Its limitations are obviously the restricted removal close to the growth in the lower areas. It may be applicable for certain lesions low in the rectum, but its worth has yet to be proved when compared with the more radical Hockenegg procedure, and for lesions at that level when compared with results of abdominoperineal resection.

DISCUSSION.—What will be the limits for which anterior resection of the rectum and anastomosis may be accomplished? Apparently, any segment down to a distance of five centimeters above the anal outlet. Since the anal canal is three centimeters in length and two centimeters above that is a very short rectal segment almost all the rectum may be removed and continuity restored transabdominally. I have found that I can remove, transabdominally, any growth the lower limit of which is eight centimeters or above from the *external* anal sphincter. This allows for the removal of at least three centimeters of rectum below the lowest gross extension of the growth, or section of the rectum, five centimeters above the anal outlet. Apparently Wangenstein has found the limitations of anterior resection to be about the same when he says: "Strange as it may seem, after mobilization, anastomosis may be effected . . . as close as five centimeters from the anus."

It will be more questionable whether resection and anastomosis should be

employed for the lower rectal growths. For the higher lesions virtually the same radical removal may be effected as by abdominoperineal resections, whereas in the lower lesions, the pelvic fascia and lavator ani are left in close proximity for lateral spread from the growth. Fortunately most carcinomas

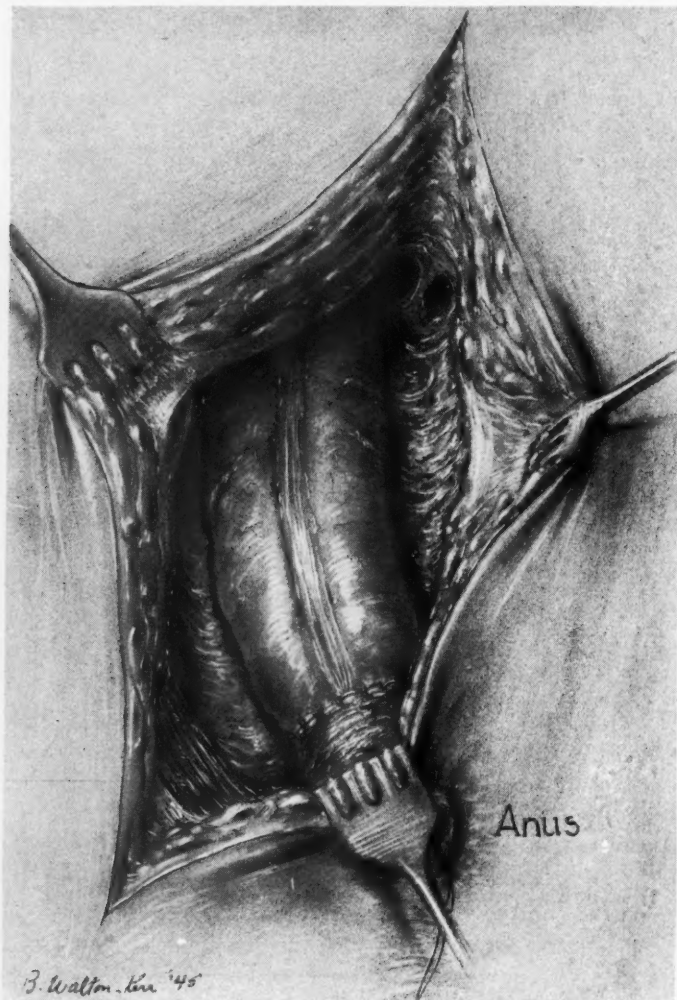


FIG. 7.—The sigmoid is anastomosed to the short stump of the rectum. Because of the danger of sloughing, a complimentary abdominal colostomy is essential.

of the rectum are not in the lowest segment. Bacon estimates, from a study of distribution of rectal cancer in 1,401 cases, that only one-fifth of rectal carcinomas are in the last seven and one-half centimeters of the anorectal canal. Mandl states that in 655 cases, the carcinoma was in the segment up to four centimeters (of the rectum) in 29 per cent, and between four and ten centimeters in 45 per cent. Allowing three centimeters for the length of the anus,

RESECTION OF THE RECTUM

Mandl's figures would indicate that 29 per cent of carcinomas of the rectum are found in the last seven centimeters of the anorectal canal and 74 per cent in the last 13 centimeters.

What significance preservation of the sphincter will have on the recurrence rate is not yet determined. If the mortality rate is tremendously increased by a greater evidence of recurrences following partial resection of the rectum, the operation will again be abandoned in favor of the Miles' operation. If, however, the five-year cure rate is as good with sphincter preservation, it definitely becomes the procedure of choice, for, who would have a colostomy when they can have an equal chance for life without one. The initial reports are favorable particularly that of Babcock and Bacon whose 81 per cent survival rate for three years is not surpassed by that of other procedures.

Even though not yet obvious, it is probably true that the assay of the value of operations with restoration of continuity will have to be made, not for the entire rectum but for different sections of the rectum. Thus, it would be expected that anterior resections with anastomosis may yield better results for high lesions than for low lesions when compared to abdominoperineal resections for similar groups.

Even if recurrences were only slightly more common, preservation of the sphincter may still be justified when surgical judgment, as it should be, considers the value of restitution to normalcy a premium in addition to preservation of life with a colostomy. Thus, though it may be difficult to evaluate mathematically in 100 individuals with cancer of the rectum, the salvage of 40 lives with normal rectal function may be worth the salvage of 50 with colostomies.

A point of great practical knowledge is how low a growth may be removed transabdominally and permit the continuity of the bowel to be established. Undoubtedly several factors influence this answer. The persistence of the surgeon and his technical accuracy will be a great determining factor and the amount of bowel which it is essential to remove beyond the gross end of the growth, is another. For those who are convinced that abdominoperineal resection alone removes enough, resection with anastomosis may seem insufficiently radical, but for those who are inclined to keep an open mind on the entire problem, partial resection of the rectum seems to offer excellent possibilities, not only for curing people with rectal cancer, but of curing them without a colostomy.

SUMMARY

Almost all of the rectum may be removed, and continuity reestablished transabdominally. In 20 resections of the rectosigmoid and rectum for carcinoma, restoration was attempted in 13. When the growth was as high as eight centimeters above the external anal outlet, it was removed and the rectum reconstructed transabdominally. This has promise of being the operation of choice for the majority of rectal cancers.

An operation is described for combined abdomino-ischial resection for low rectal growths. The results would seem to justify further attempts.

REFERENCES

- ¹ Babcock, W. Wayne: The Babcock One-stage Operation for Carcinoma of the Rectosigmoid with Elimination of Colostomy. *Treatment of Cancer and Allied Diseases*, Edited by George Pack and Edward Livingston. Paul B. Hoeber, Inc. New York-London, 1940.
- ² Babcock, W. W., and Bacon, H. E.: Operative Treatment of Cancer of the Large Bowel without Colostomy. *Arch. Surg.*, **46**, 253, 1943.
- ³ Bacon, Harry E.: Evolution of Sphincter Muscle Preservation and Reestablishment of Continuity in the Operative Treatment of Rectal and Sigmoidal Cancer, *Surg. Gynec. & Obst.*, **81**, 113, 1945.
- ⁴ Collier, F. A., Kay, E. B., and MacIntyre: Regional Lymphatic Metastasis of Carcinoma of the Rectum. *Surgery*, **8**, 294, 1940.
- ⁵ Dixon, Claude F.: Surgical Removal of Lesions Occurring in the Sigmoid and Rectosigmoid. *Am. Jour. of Surg.*, **46**, 12, 1939.
- ⁶ Dixon, Claude F.: Anterior Resection for Carcinoma Low in the Sigmoid and Rectosigmoid. *Surgery*, **15**, 367, 1944.
- ⁷ Gilchrist, R. K., and David, Vernon C.: Lymphatic Spread of Carcinoma of the Rectum. *ANNALS OF SURGERY*, **108**, 621, 1938.
- ⁸ Kraske, H.: Zur Operation des Mastdarmkrebses. *Bruns' Beitrage z. klin. Chir.*, **142**, 408, 1928.
- ⁹ Kraske, P.: Über die Weitere Entwicklung der Operation Hochsitzender Mastdarmkrebs, *Arch. f. klin. Chir.*, **80**, 634, 1906.
- ¹⁰ Lockhart-Mummery, J. P.: *Diseases of the Rectum and Colon*. 2nd Edition Wm. Wood & Co. 1934, Baltimore.
- ¹¹ Lockhart-Mummery, J. P.: The Surgical Treatment of Cancer of the Rectum. *Am. Jour. of Surg.*, **46**, 40, 1939.
- ¹² Mandl, Felix: Maintenance of Continence in Operations for Carcinoma of the Rectum. *Jour. of the Internat. Coll. of Surg.*, **3**, 11, 1940.
- ¹³ Mandl, Felix: The Extended Sacral Operation for Cancer of the Rectum. *Jour. of the Internat. Coll. of Surg.*, **4**, 424, 1941.
- ¹⁴ Mandl, Felix: Technique and Results of Primary and Secondary Pull-through Operation after Removal of Tumors of the Rectum and Rectosigmoid. *Surgery*, **18**, 318, 1945.
- ¹⁵ Miles, W. Ernest: The Radical Abdomino-perineal operation for Cancer of the Rectum and of the Pelvic colon. *Brit. Med. Jour.*, **2**, 941, 1910.
- ¹⁶ Miles, W. Ernest: The Present Position of the Radical Abdomino-perineal Operation for Cancer of the Rectum in Regard to Mortality and Postoperative Recurrence. *Proc. Roy. Soc. Med.*, **24**, 989, 1931.
- ¹⁷ Miles, W. Ernest: The Problem of the Surgical Treatment of Cancer of the Rectum. *Am. Jour. of Surg.*, **46**, 26, 1939.
- ¹⁸ Petermann, J.: Über Mastdarmkrebs. *Arch. f. klin. Chir.*, **80**, 1, 1906.
- ¹⁹ Wangenstein, Owen H.: Primary Resection (Closed Anastomosis) of Rectal Ampulla for Malignancy with Preservation of Sphincter Function. *Surg. Gynec. and Obst.*, **81**, 1, 1945.

FURTHER OBSERVATIONS UPON IMPERFORATE ANUS*

DR. ROBERT L. RHODES

AUGUSTA, GA.

WITH THIS MALFORMATION occurring in about one in every 5,000 babies born and over 2.5 million babies annually, 500 or more each year have this defect—that is a sufficient number for us to have a clear-cut plan of action or treatment to give these babies an average chance at a normal life and not subject them to haphazard bungling or consign them to a colostomy life, with all its attendant ills for child and mother.

Such a plan¹ I submitted before this Association 12 years ago, with the report of a case. Incidentally, this girl is living and well, 13 years of age, and has developed normally, with perfect control over her bowels. I did not enter into any discussion or criticism of previous suggestions or methods of treatment but reported a case with the process of reasoning as it progressed and the developed technic. It has been amazing to find so many surgeons who are not familiar with the method and appalling the number of these infants who are literally taken from the delivery room to the operating table and a colostomy established. Thus, my excuse for again bringing it to your attention.

This state of affairs is very largely due to authors of books on Surgery, and contributors to Systems of Surgery, who not only ignore my simple procedure but continue to offer misleading or inaccurate suggestions or statements for the guidance of the surgeon suddenly confronted with this malformation. I found such to be true 13 years ago but was not impressed by the information obtained and proceeded to work out the technic as reported. For instance, David in the current reference works, "Practice of Surgery," published by Prior and Nelson's "Loose Leaf Living Surgery," says "Wangenstein and Rice procure a plain film of the abdomen and pelvis with the child held in an inverted position to determine the outline of the terminal bowel by the gas present in it." It is true that gas rises but it is also true that gravity pulls earthward—the terminal bowel may be pulled one-half to one inch further from the perineum when the child is inverted. I showed a picture taken with the child on its side, with knees firmly flexed against the abdomen to force the terminal bowel as low as possible and I will show in the slides a little later the very definite advantage of this position and the more accurate information derived.

Furthermore, David adds, "if the child is not in good condition, and perhaps in any event in this type of high-lying rectum, a colostomy should be performed as a life-saving procedure, hoping at a later date to establish continuity of the bowel. In this particular situation the prognosis is grave, but

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

of paramount importance is the early diagnosis of imperforate anus so that steps may be taken to relieve the obstruction before the devastating effects of a large bowel obstruction are in evidence." My answer to that is that experience has borne out a statement in my first discussion: "We reasoned that the newborn with a sterile alimentary tract could not and would not die of the toxins of intestinal obstruction even after several days," and I might have



FIG. 1.—(This and the following three illustrations are of Case 4). Child held up by its feet. Note how high is the terminal bowel and rounded end.

added that sterilized food and sterilized water, such as are given to babies, markedly delay the establishment of intestinal flora. Such statements frighten one into rushing in too soon. As a matter of fact, it is not the toxins resultant from intestinal obstruction that cause anxiety, as I will show in the report of a most unusual case, but the increasing regurgitant vomiting, with the danger of aspiration suffocation as the abdomen becomes more and more distended. This danger can be markedly avoided by keeping the baby on its ventral surface entirely.

The several points I tried to make, which I now wish to emphasize and to add several additional ones, are (1) that there is no need to hurry, but

IMPERFORATE ANUS

give them time to develop all they have, encouraged by giving water and feeding normally; (2) repeated roentgenograms either fluoroscopic or films with the baby on its side and the knees firmly flexed against the abdomen will show the terminal bowel at its lowest point; (3) finger pressure in the perineum towards the terminal bowel will reveal the distance to be covered: (4) small incision to permit the finger to bore its way to the bowel, instead of laying the perineum wide open and thus open a large raw area for secondary



FIG. 2.—Taken immediately after Fig. 1, but with child lying on its side and knees flexed. The projection of the terminal bowel is about one inch lower than in Fig. 1, thus giving much more accurate information.

infection as well as destruction of the sphincter; (5) place the incision in the approximate area of the sphincter and try to cut it in only one place, an advantage of the small incision; (6) when the bowel is reached sweep the finger around it to free it, grasp the lowest point with a clamp and with gentle traction on this, gradually free it all around until it can be brought down as far as possible; (7) if the entire bowel can be brought to the skin surface, open it and suture to the surrounding skin, if only part way, anchor it on the four quadrants to the surrounding muscles, open the end, free and bring the mucosa on down and suture to the skin; (8) because of the danger of skin contraction these cases must be dilated weekly at least, until they are about

one year old; and (9) no anesthesia is required when operating through the perineum during the first week of life.

I never have roentgenograms taken of them until they are 24 hours old; seldom until they are 48 hours old; and never operate until I am convinced that the bowel cannot be made to descend further, or has reached the skin. In some cases this will occur in 48 hours, in others it will not take place until they are four or five days old.



FIG. 3.—Twenty-four hours later the distended bowel has reached the tip of the coccyx, about half an inch lower than Fig. 2.

The appearance of meconium in the urine, indicative of fistula into the urinary tract, with the danger of ascending urinary infection, is not the "bugbear" we have been led to believe, for the simple reason of the lack of intestinal flora at this age. It is, therefore, not an indication for hasty action. Nor will it, in several days, reach sufficient size that it will not heal spontaneously when intrabowel pressure is relieved by appropriate operation. I wish to most emphatically stress my belief that the overwhelming majority of these cases can be reached through the perineum if they are permitted sufficient time to develop or distend their terminal bowel. Perhaps there may be a thousandth case that will require colostomy. A point, here, to remember

IMPERFORATE ANUS

is to establish the colostomy high in the sigmoid to leave redundant bowel below, in the hope that as the child grows it may develop sufficient length to be carried to the perineum and the establishment of an outlet. Should distention become too extreme, a tube may be passed easily through the nose into the stomach and deflate, or on into the small bowel if necessary. The gas or air bubble in the terminal bowel will not be greatly influenced by the deflation above.



FIG. 4.—Firm finger pressure on the perineum lacks about 1.5 cm. of reaching the tip of the bowel but that the latter can be reached, with a little more tedious dissection, through the perineum than when the bowel is low enough for finger pressure to reach it.

The following case reports have been selected to demonstrate the application of these fundamental principles:

CASE REPORT

Case 1.—Baby R. E. is the only one upon whom I have performed a colostomy since the development of the above technic. The child was born in a neighboring hospital, November 12, 1941, at 10:30 P.M., and was sent over to me the following morning. Roentgenologic studies showed no development of the bowel below the sigmoid, which was redundant, that is, no rectum or anal canal and, in addition, "maldevelopment of the sacral bones and coccyx." When 90 hours old he began to pass meconium in his urine, therefore, we at once established a colostomy, under local anesthesia, because of

the fear of ascending urinary infection. After a short time the meconium disappeared from the urine, and he has developed normally otherwise to date. In several more years we shall recheck him to determine the advisability of attempting to establish bowel continuity to the perineum and later closure of the colostomy.

Case 2.—Baby C. T. D., admitted on March 11, 1945, is a "believe it or not" Ripley case, in that at four months of age he had never had a normal movement of solid or semisolid material, and is proof that one does not have to fear large bowel obstruction in these cases. This was somewhat of a "special dispensation child" when he came after his parents had given up all hope of any offspring, discouraged by 14 years of barren life. He was well-developed at birth, weighing 8.5 pounds, except for an imperforate anus, but he had a definite dimple in the anal area. His parents were advised and urged to bring him for operation, but they refused. When three days old, a small fistula appeared near the base of the scrotum through which liquid and gas were evacuated daily. He was breast-fed and exceptionally large at four months of age, weight 16.5 pounds, quite normal in every respect except for the imperforate anus and fistula, which permitted the passage of only a 2 mm. probe. At operation, under light ether anesthesia, a probe was threaded through the fistulous tract into the rectum, a circular incision was made around the orifice and extended in a straight line posteriorly into the middle of the dimple. The fistulous tract was dissected down to the bowel, which was mobilized sufficiently to be brought down until it could be resected above the fistulous communication and its end sutured all around to the skin with numerous interrupted fine silk sutures. Convalescence was uneventful, and when checked four months later, except for the small scar the anal region appeared perfectly normal, his bowels moved normally, not a steady leakage of lack of control, and his mother had already begun to train him in this respect.

Case 3.—Baby P. D., born 5:30 A.M. May 30, 1944, normal in every respect except for imperforate anus and no dimple. A roentgenogram, May 31, 1944, showed distended gastro-intestinal tract down to the terminal end of the sigmoid, but no evidence of any rectal ampulla. The next morning distention had extended to about half way down the rectum, but a stricture was evident at the rectosigmoid junction, and a fistulous opening appeared at the middle of the posterior surface of the scrotum through which a small amount of meconium escaped. The urine did not contain meconium, therefore, the fistula did not extend into the urinary tract. By late afternoon the entire rectal ampulla was distended but the stricture at the rectosigmoid persisted. The following morning, June 2, 1944, the stricture had dilated, the rectum was well-distended, down almost to the perineum. Operation was performed at 80 hours age, in the manner of the preceding case. Convalescence was uneventful.

Case 4.—Baby G. was born 7:40 A.M., March 21, 1945, without anus or dimple, but in other respects normal. March 23, 1945, a roentgenogram showed distention to rectosigmoid junction; on March 24, 1945, distention had extended to about half way to the rectal ampulla, the end being at the level of the sacrococcygeal junction; March 25, 1945, distention had reached the tip of the coccyx, apparently filling the rectum, but there was no evidence of an anal canal, and firm pressure of the finger tip in the perineum lacked 1.5 cm. of reaching the bowel end. The abdomen was quite distended and he was regurgitating almost constantly, so much so that operation was deemed advisable. It was performed at 3:30 P.M., when the infant was 104 hours old. In this case the bowel could not be mobilized or stretched sufficiently to be brought to the skin but was sutured at four points (quadrants) to the surrounding muscles with chromic catgut, the end opened, bowel contents evacuated, thoroughly irrigated, the mucous membrane freed, brought to the skin and sutured with numerous interrupted fine silk.

Convalescence was uneventful, and his mother brought him in weekly for dilatations until he was four months old, when they moved away. She was supplied with a rubber dilator (Wales bougie), instructed how to use it and urged to do so weekly. She, how-

IMPERFORATE ANUS

ever, was very indifferent about it, and at 5.5 months of age brought him back quite distended, because of contracture of the anal skin which was easily dilated, copious evacuation, with much gas, immediately occurred and the distention was relieved. She insisted that the distention had occurred when she began to feed him Pablum. Again, she was indifferent about dilatations and at seven months of age he was admitted to the hospital as a Staff case, enormously distended, his bowels were not moving but he was having some escape of intestinal contents through his urethra. Because he had been my private case I was asked to see him, and found his anus almost completely closed, so nearly so that I had to use a fine-pointed hemostat to find the orifice, which was dilated with the clamp until a rectal dilator could be inserted to fully dilate. With daily dilatations and enemas his bowels moved well, the fistula into the urethra promptly healed, the distention was partially relieved but not entirely until he was placed upon a high protein low starch diet, after which he cleared up without further trouble.

REFERENCE

- 1 Rhodes, Robert L.: Imperforate Anus: A Suggested Mode of Handling. Amer. Jour. of Surg., New Series, 24, No. 3, 828-831, 1934; *idem*: Transactions of the Southern Surgical Association 1933, pages 634-637.

DISCUSSION.—DR. JOSEPH D. COLLINS, Portsmouth, Va.: I wish to emphasize the important point that Doctor Rhodes made in his paper, namely, that it is not imperative to operate upon these babies immediately. Doctor Rhodes has effectively demonstrated this by his report of the case of imperforate anus which he saw for the first time when the baby was four months old.

I have a case to report which even more strikingly illustrates the point which Doctor Rhodes has brought up. About five years ago a woman consulted me regarding a male baby that was then approximately one year old. She stated that this child had never had a bowel movement. Upon examination I found no evidence of any anus, in fact there was not even a dimple, but there was a small opening in the perineum just posterior to the scrotum which ejected at intervals a very fine stream of black fluid and flatus. This child was well-nourished and, except for the abnormality just described, was apparently a normal child. I advised her to have the baby admitted to the hospital for observation and necessary operation. She stated, however, that the baby had recently been exposed to measles and she wanted to wait until after the period of incubation was over. Of course I agreed.

I saw no more of her until two years ago when she brought the child to me again. He was now a boy four years old, perfectly well-developed and normal in every way with the exception of the absence of his anus. He had a rather large abdomen, and upon palpation masses of fecal matter could easily be felt. His mother said he played the same as her other children and apparently suffered no ill effects, except that at times he would have spells of vomiting, especially if he overloaded his stomach. A plain roentgenogram easily demonstrated the enormously distended colon filled with fecal material. It was not possible to inject this small fistulous opening with barium, but the roentgen ray technician was able to introduce a small fuse wire through the fistulous tract into the rectum, which the roentgenogram showed to be about one inch above the level of the skin. Leaving this fuse wire in the opening and using it as a guide, I dissected out this sinus and found the lower end of the rectum. I then dissected out the rectum, brought it down and sutured it to the skin, after the manner of the old Whitehead operation for hemorrhoids. I was able to find the rudiments of the sphincter, which has functioned fairly well. The child is now perfectly well, with fairly good control.

The mother of this child has had ten children, two of whom had to be operated upon for congenital pyloric stenosis when about six weeks old.

DR. HUGH A. GAMBLE, Greenville, Miss.: I was especially interested in Doctor Rhodes' paper, particularly as to the time that he stated would be safe to delay surgical intervention. Many of the cases we do not see early. I have had three cases; one I saw within 24 hours, another in three days and another about the fifth day.

In the first case the terminal bowel could be reached by blunt section and was opened and sutured to the skin.

In the second the bowel had not, in my opinion, descended low enough for an attempt to be made to reach it from below, and in the third there was a fistulous communication between the vagina and the rectum and also a small opening along the lower border of the sacrum. There was a slight dimple where the anus should have been.

In the second case, in which the terminal bowel was high up, a cecostomy was performed in order to keep the left side of the abdomen clean for future operations. This child disappeared and I have not been able to find what the ultimate outcome has been.

In these cases of imperforate anus the bowel can come down low enough to be reached by blunt dissection from below. Again there are some cases in which the terminus of the bowel is so high as to necessitate either a cecostomy or colostomy. Also, it is often found that there are fistulous tracts joining the terminal bowel with the bladder, urethra or vagina.

In the last case, which I saw about six months ago, there was a rectovaginal fistula, small in size, and also a fistulous tract opening along the lower border of the sacrum. It was not difficult to make an opening where the anus should be, bring the bowel down and attach it to the skin margin. Fortunately, the fistulous tracts have closed spontaneously.

In the after treatment there is a tendency for the skin to contract around the external orifice and it is necessary to continue dilatation over a prolonged period of time.

As Doctor Rhodes has emphasized, I do not think that a moderate delay is of any special significance in handling these cases. In fact, one is in much better position to determine what procedure to adopt after giving the terminal bowel an opportunity to descend as low as possible.

DR. FRANK H. LAHEY, Boston, Mass.: I had hoped that someone else would rise to discuss Doctor Mahorner's paper from the point of view of the effect of procedures to preserve the sphincter ani, such as he and others have described, upon the ultimate nonrecurrence rate; the immediate general mortality rate; and the postoperative complication rate, such as stricture and perianal fistulae.

Mr. Robert Moses, of New York, a short time ago, made a most apt remark in a debate of somewhat acute character. He said: "Now we have a good contentious subject and we can choose up sides and have a contest." About the principles involved in the paper one can only say he has to select his side now and, later, if he is wrong, so much harm will have been done one way or the other that he will regret it. To answer the above questions will take time and cases, but I want, unreservedly, to choose my position now and give the reasons for doing so. I have chosen to continue to support complete abdominoperineal radical resection with a permanent abdominal colostomy, for these reasons: I feel less concerned in a patient with carcinoma of the rectum with conserving his or her sphincter ani than I do with saving his life. I am certain that one has but one opportunity surgically to give these patients a chance to be in the group which does not have recurrence, and that is at the time the first operation is done. It is the completeness, the radicalness and the aggressiveness of this first operation which so positively influences how many cases will be in the five-year nonrecurrence group and how many will not be in this group.

With the above principles in mind and after having dealt with 2,000 of these cases as we have, in fat people, in thin people, in good risks, in bad risks, with small lesions, with large lesions, with associated inflammatory processes and without associated inflammatory processes I do not want to be handicapped by any technical procedures related to pelvic anastomoses and preservation of the perineal sphincter. I do not want to be concerned with whether or not enough loop of sigmoid or descending colon will be left to get it down to the remaining stump of pelvic rectum. I do not want to be limited in any way as to how high I can go in removing nodes along the iliacs, as relates to the blood supply of the sigmoid and descending colon. I know with a colostomy I can take out the entire sigmoid, rectosigmoid and descending colon and make a colostomy in the transverse colon if I want to. By means of this, if I choose to, I can remove nodes as high as the point where the jejunum becomes retroperitoneal.

I became interested some years ago in anterior resection, leaving a small lower segment of rectum behind in high lesions to avoid the necessity of posterior removal,

IMPERFORATE ANUS

particularly in bad risk cases. There were so many recurrences in the remaining stump with this operation that we were forced to abandon it.

We have reported our end-results in 1,800 cases of carcinoma of the colon and rectum in which the highest percentage of five-year nonrecurrence rates occurred in those patients with no nodes, no local extension and no blood vessel invasion, 90 per cent. The lowest five-year nonrecurrence rate, 14 per cent, was in those cases in which there was blood vessel invasion. We, therefore, are interested only in a type of operation which fulfills for us three requirements: The removal of the lesion with the widest possible margin of safety on either side of it; the largest amount of node-bearing structures around it; and the widest block removal of adjacent blood vessels.

In my opinion, altogether too much apprehension has been created about a colostomy. Too many of the opinions that a colostomy is so terrible are based upon a palliative colostomy and not a colostomy after a lesion has been removed. We have literally hundreds of patients with good functioning colostomies who wear no bags, who do everything, and who are quite satisfied with their life and existence. A well-established colostomy in a patient who is well educated in its management is by no means the hardship some writers suggest it to be. Much of the energy devoted to popularizing preservation of anal sphincters at the price of limiting the radicalness of the removal of the lesion is based upon the patient's sentimental objection to a colostomy. In my mind this is quite wrong, (1) because the patient's opinion and decision about a colostomy is an entirely sentimental one based upon no knowledge of how well it works and certainly with no experience with what the effect of the accomplishment of retention of his perineal sphincters will have upon his life immediately, his postoperative complications and his ultimate freedom from recurrence of the malignant lesion.

Even when results with this operation at the end of five years are reported, they will still be difficult to evaluate unless groups of cases for both methods in terms of operability rate, how many palliative resections are done and the selectiveness of the cases submitted to these radical procedures are compared.

In my hands, I know of no operation which can be more technically difficult than some of these abdominosacral resections, and when I think of the difficulties I have had with some of these cases to which would need to be added pelvic anastomoses, I cannot avoid the opinion that ultimately these attempts to obtain two things at one time will prove that you never get something for nothing.

DR. HOWARD MAHORNER, New Orleans, La. (closing): We must certainly listen to Doctor Lahey because of his tremendous experience and because of what I think is his unflinching judgment about surgical procedures. I respect his opinion and at the same time I hope for these patients justification for restoring continuity. I do have some sentiment about the sphincter; in spite of a higher mortality rate, reestablishment of continuity may be justified when surgical judgment is tempered with philosophy. It is difficult to measure numerically, but I have an idea that 40 patients living with restored continuity is worth 50 living with colostomies.

CONGENITAL DEFECT OF THE ABDOMINAL WALL IN THE NEW BORN*

(GASTROSCHISIS)

FRANK S. JOHNS, M.D.

JOHNSTON—WILLIS HOSPITAL

RICHMOND, VA.

SURGICAL RARITIES are of limited interest. My subject, I hope, proves an exception to this generality. It concerns an unusual congenital defect, with a brief study of its history and etiology, and the record of a procedure for its successful repair. The case is one of gastroschisis with a large congenital defect of the abdominal wall, operated upon 30 minutes after birth; the result is a surviving and normal child, now three and one-half years old.

"Embryology in disorder," according to Ballantyne, is "teratology." With this observation we propose a brief summary of the theories which have been advanced for the occurrence of gastroschisis. Students of antenatal pathology are agreed that amniotic displacement is the most frequent factor in the production of monstrosities. They believe that gastroschisis, like the great majority of the deformities which affect the unborn infant, has an embryologic and amniotic explanation. Since the embryonic period is limited to the interval between the first and sixth weeks of prenatal life, this accident, which is a structural abnormality and not one of growth, originates with the embryo and its environment.

Normally the embryo floats free in the liquor amnii; but if from *scarceness* of the liquor or from adhesiveness of the embryo, or of the walls of the embryonic sac, the amnion comes in contact with and becomes united to the embryo, then that part of the embryo so affected is arrested or distorted in its development, and a malformation results. Although enunciated 30 years ago, in 1905, Ballantyne's theory is both logical and lucid, and we accept it as authority for the etiology of this type of congenital defect. He also cites the fact that the teratogenic pressure on the embryo is not always amniotic. It may be caused by pelvic or abdominal tumors, by deformities of the uterus or narrowness of a tubal gestation sac, by the umbilical cord or even by one part of the embryo compressing another. As surgeons, we face a practical responsibility arising from this embryologic concept. We must impress on our colleagues the importance of removing all pelvic tumors, particularly during the child-bearing period.

The literature of this abnormality is voluminous and unorganized. The subject has been difficult to study on that account, and a part of my purpose in its presentation has been an attempt to re-edit the bibliography for future reviewers. The problem of nomenclature appears promptly, for the very name of this teratologic accident is still undetermined. The best term currently used

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

for it is a Greek word, *gastroschisis*, more freely translatable as "belly-cleft," and defined as "a congenital malformation in which the abdomen remains open." It was coined for an abnormality whose occurrence is rare but which has been reported at intervals since the year 1557. In the long uncatalogued annals of this anomaly, many other titles are used to describe it. Cullen prefers "amniotic hernia" for his discussion. For Bernstein's bibliography, only six of 28 references to gastroschisis include the word. Taruffi, faced with difficulties in Italian terminology, was one of the first to coin and use the collective title. In 1894, for his "Storia della Teratologia," he used "gastroschisis" adding many syllables for a proposed "regional nomenclature" of the defect. This he arranged in seven definitive but cumbersome group-heads: (1) Epigastroschisis; (2) epiomphaloschisis; (3) thoraco-omphaloschisis; (4) hyogastroschisis; (5) hypogastroetroschisis; (6) pleurosomataschicis; and (7) holo-gastrostroschisis.

In 1812, J. F. Meckel, the elder, described this defect as "partial fissure of the anterior surface of the body." The majority of German authors have briefed it to "bauchspalten," or "abdominal fissure." Spanish writers describe it as "fissura abdominalis completa." French and Russian literature report "agenesia of the abdominal wall." In English, "eventration," "amniotic hernia," "congenital absence of part of the abdominal wall," "massive ectopia intestinalis," and "nonclosure of the abdomen" are other variations. Besides all these, many cases of gastroschisis are completely lost to reviewers in titles less descriptive. In 1931, Poloyas deplored this fact.

"A complete search of the literature is difficult," he declared, "because there is no standard classification of monsters, which are often incorrectly classified. . . . Cases are hidden in titles which are often ambiguous, "An Unusual Monstrosity," "A Rare Fetal Anomaly."

He concludes his report of a case of "nosencephaly with eventration of the abdominal and chest organs, etc.," with a plea for "standard nomenclature and accurate titles of case reports"—but the difficulty remains.

A full survey of the literature is limited by its undetermined nomenclature. But all reports of this defect which we have found, fall into three groups, easily differentiated, not by *region* but by *degree*. Chronologically, the same groups appear. With rare exceptions, the earlier reports are all fatalities. It is tempting but unprofitable to ask how many of them could have been rescued by more surgical knowledge and better technic.

The exact number of reported cases of this congenital defect, has not been fully catalogued. The first known case, according to Bernstein, was reported by Lycosthenes in 1557; and from that time on, gastroschisis (though rarely so-called) is not uncommon in the literature of teratology.

In the references available for our study of the subject we have found 96 case reports. Sixty-eight of these we find belong in Group I, stillborn monstrosities. Nineteen cases compose Group II, child living at birth, normal except for his abdominal wall defect, but no attempt made to repair it. Group

III includes the nine cases we have found in the literature, including this case report, in which attempt was made to repair the defect.

Into Group I, unhappily the largest, we place all cases reported as impossible to repair. The majority of them concern the necrology of a stillborn fetus, for prematurity is characteristic of gastroschisis. They include extreme teratologic deformities besides the eviscerated organs of the abdomen. Exstrophy has occurred long before delivery and the eventrated organs have grown to enormous disproportions with the empty and shrunken cavity behind them. In all such cases, the report is that there could be no question of a possible closure, or of regeneration of the defective abdominal wall, even if the child had been born alive. For these monstrous infants, according to Kleiner, "an operative procedure is wholly unthinkable." In both of his reported cases he says: "the fetus on account of his malformation is not capable of life; he is solely interesting as an exhibit of pathologic anatomy." However, Group I also includes a number of cases of stillborn gastroschises in which the infant was delivered at full term and normal in all respects besides his abdominal defect.

In Group II, which includes only "simple" gastroschises, the number of cases is much smaller than Group I. A search of many titles, ambiguous and otherwise, is rewarded by the occasional report of an infant born alive and normal except for a defective abdominal wall; but these too have all failed to survive. Their organs were eventrated through the abdominal defect at birth, and no surgical repair was accomplished or attempted.

A chronologic list of the 19 cases described as Group II, in our survey, includes the following authors. We have added the length of time each infant lived.

GROUP II

Calder, J.	1763	Child lived 4 days
(Unsigned) Report in the J.de Pract. Heill. Berlin	1805	Child lived 58 hours
Ogle, J. W.	1864	Child lived 29 hours
Batalla	1874	Child lived 4 days
Crowther, B.	1878	Child lived 15 hours
Kramarenko	1888	Child lived 48 hours
Todd, G. B.	1895	Child lived 15 days
Schmidt	1900	Child lived 4 days
Johnston, J. A.	1903	Child lived 48 hours
Tate, M. A.	1903	Child lived 4 days
Lee, D. F.	1907	Child lived 28 hours
Forsyth, C. B.	1908	Child lived 26 hours
Das, K.	1908	Child lived 10 minutes
Aranow	1910	Child lived 30 minutes
Bott, Stanley	1911	Child lived
Fletcher, M. A.	1928	Child lived 14 days
Kleine, H. O.	1929	Child lived 15 minutes
Hyde, Charles T.	1930	Child lived 16 hours
Purdy, W. and Stofer, B. E.	1934	Child lived 8 days
Krauss, F.	1936	Child lived 2 hours

There are 19 cases in this group. They have lived from a few minutes to eight days, and there is evidence of the striking hardihood and will-to-live in the newborn in the eager attempts made by these abnormal infants to take nourishment, and also in their normal excretory functions. The causes of

death are variously reported as peritonitis, gangrene, pneumonia, dehydration, exhaustion. To these we may add failure to make surgical repair of the defect.

For one of these cases, Forsyth, in 1908, reports a half-hearted attempt to replace an infant's extruded stomach and small intestines inside the abdomen. But he did so only to make the monstrosity "more presentable" to its parents. In doing this he expelled a large quantity of yellow amniotic fluid from the child's mouth and nose, after which the attending physician resorted to artificial respiration and the baby began to breathe regularly and cried lustily. Bowels and kidneys functionated several times and the child nursed, but kept up a whining cry until it died after 26 hours. This is the only attempted surgical repair which is recorded among these fatal cases of the abnormality.

Group III, though the smallest, is by far the most interesting part of our survey. It includes all the cases we have found in which attempts to repair the defect were undertaken. In six of the nine cases found in this group, the result has been a living and normal child.

William P. Hogue, of West Virginia, in 1887, reports the first successful repair of this congenital defect. His patient was a Negro male infant, delivered by a midwife. He was called to see it an hour and a half after birth. The child had a small defect in the abdominal wall, an opening one by one and a half inches in diameter in the region of the umbilicus. Through this opening the infant's bowels passed out in a mass reaching down to the pubes. The edges of the defect were smooth and glossy. He closed the opening with strips of plaster put on straight and diagonally. At the end of five weeks, he was surprised to find the child thriving, with his opening entirely and permanently closed. The report ends with the fact that the child is now living and about eight years old.

Benedict's case, in 1895, is erroneously entitled "An Enormous Congenital Umbilical Hernia." It reports a protrusion of the abdominal viscera through an opening four inches in diameter in the abdominal wall. The color of the mass at birth was a "dark bluish-black," and the covering was so thin that the movements of the viscera within could be plainly seen. Fifty-three hours later, Benedict did a rather extensive repair operation, under chloroform, which lasted 50 minutes. He reports: "The approximation was made upon the subcutaneous surface rather than upon edge of skin. This was held together by three silver pins, an inch long, wound with silk in the figure-of-8 way, and immediate apposition obtained by black silk interrupted sutures."

Three weeks later, when his report was written, the child was healed and was apparently normal and well.

Caffier's case, reported in 1929, had a defect "the size of a man's cuff" through which the abdominal contents protruded. Only about one-quarter of this mass was covered with a peritoneal "veil." It is interesting to note that conservative treatment only was used. This consisted of alcohol poultices strapped over the defect's protruding contents. The eventration gradually subsided into the abdominal cavity. After three and a half months the defect was entirely healed over, leaving only a slightly protruding herniation.

Dr. Gamble's case, reported in 1930, describes a white male born with complete absence of the abdominal wall. The defect was 3.5 inches in diameter and covered with a thin translucent membrane. During delivery the stomach and liver were both totally everted through this defect. The defect was repaired by a modified Mayo operation for umbilical hernia. During operation it was noted that there was almost complete absence of the suspensory ligaments of the liver, and in order to maintain the liver in position, it was necessary to suture the round ligament to the costal margin. An excellent closure was effected. There was little shock, and the baby made an uncomplicated recovery. Reported at seven months.



FIG. 1.—Artist's sketch of defect at birth.

Koon's case had a two-inch defect through which all the intestines extruded. It was delivered at home and had to be removed some distance to the hospital, where a surgeon attempted to repair the defect under novocaine and a few drops of ether. Through-and-through sutures were used. The patient did well until the fourth day when it became dehydrated and died.

Williams reports a case of amniotic hernia which was not referred to the Surgical Department of the Medical College of Virginia until two days after birth. The child was a Negro male, well-developed and well-nourished, with no other abnormalities besides a three-inch defect of the abdominal wall. The contents of the abdomen were covered by a transparent membrane. Under ether anesthesia, an incision was made about one-quarter of an inch from the

skin edge leaving this small circle of skin attached to the membrane. The skin was undermined around the whole defect without disturbing the muscles, the excessive stump of the umbilical cord was removed, and the skin easily closed down with interrupted sutures. The baby rapidly declined and died 12 hours later.

Dry reports a difficult delivery. The child was vigorous and normal except for his large defect of the abdominal wall with complete eventration of liver, stomach, small intestines, and colon. An attempt was made to return the exposed contents into the cavity by plastic methods, but the infant succumbed the same day.

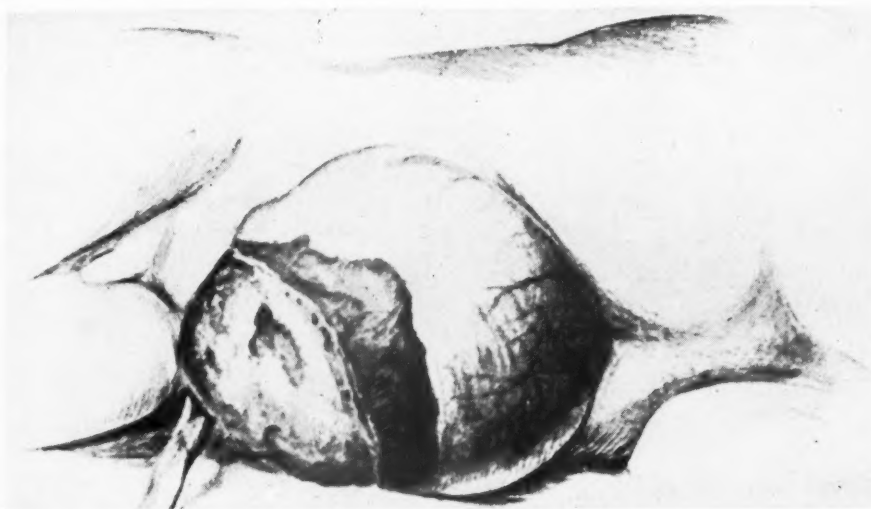


FIG. 2.—Condition at end of first week. (Prompt growth of epidermis from the outside; the amniotic covering is necrotic.)

Watkins' case, when delivered, had a large reddened mass of its viscera hanging from its abdomen. This had been eventrated through a slit, about one inch long, just to the left of the base of the umbilical cord. The viscera were the small and large bowel, both of which were thick, leathery, cyanotic and larger than normal. The opening was enlarged to two inches in the midline, when the child was 30 minutes old, and the viscera were placed in the abdominal cavity with some difficulty because of their size. The wound was closed with through-and-through sutures. Dehydration was combatted early and frequently, and 16 days later the child was dismissed from the hospital healed and gaining normally.

In making this study we have been careful to differentiate such cases from reports of true umbilical hernia, which is a far more common abnormality of the newborn, as well as from the condition known as omphalocele or exomphalos.

William Fear's case of eventration at the umbilicus is a type which has

also been confused with the literature of gastroschisis. In this case, reported in 1878, the small intestines, practically the whole of the colon and the pyloric end of the stomach protruded through a long slit in the cord. Repair was made, the organs were replaced and the child lived. A notable case, but not pertinent to the literature of defects of the abdominal wall.

Case Report.—Baby H. born July 11, 1942

Mother's History: Mrs. H., age 26, weight 156, admitted to Johnston-Willis Hospital 8:30 A. M., July 11, 1942, a patient of Dr. M. Pierce Rucker. Diagnosis: Term pregnancy; vertex R. O. A.

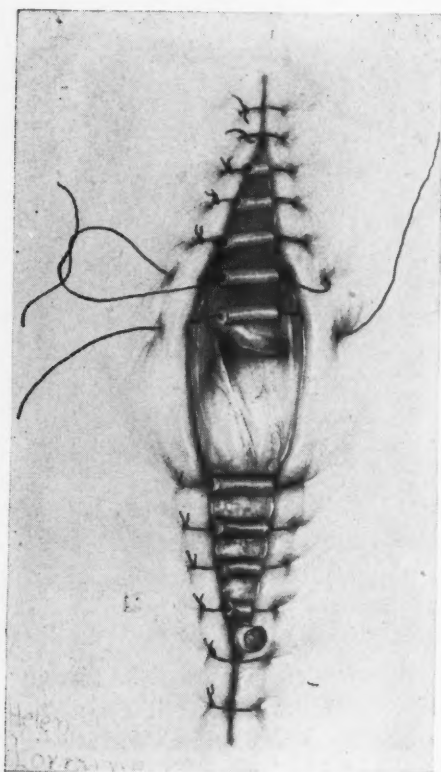


FIG. 3.—Repair made immediately after birth. Note: incision not completely closed, due to tension.

When the cervix was fully dilated and the head had rotated anteriorly, Linkart forceps were slipped on and an easy extraction was done. No cord was about the neck, external rotation was to the right. Right lateral episiotomy was done.

Baby's History: Delivered without difficulty at 4:17 P. M. Wt. 5 lbs. 11.75 oz. During delivery a large defect was noticed in the anterior abdominal wall, and care was taken lest the thin covering over the exposed abdominal viscera should be punctured. (This careful procedure had a most beneficent influence on the repair of the defect.) Saline compresses were placed on the abdomen and the baby was sent immediately to the Surgical Department.

Findings at Operation: General appearance and features were entirely normal except

Previous History: Menses appeared at 12; occur every 28 days, lasting 3 to 5 days. Other history negative. No abnormalities, no twins on either side of family.

Marital History: Married October 1, 1931. Has had three children previously. No miscarriages. First child born July 12, 1932, at 7.5 months. Labor severe and prolonged; eclampsia. Second child born September 11, 1933, at 6.5 months; lived only a few minutes. Third child born May 14, 1939, at six months; stillbirth.

History of this Pregnancy: Last menses October 7, 1941, lasted five days. Has had a bearing-down sensation; perspires freely; cough. Appetite is good. Has nocturia, gas, no dysuria, no nausea, no backache. Appears well-nourished; no skin eruption; no edema; no varicosities. Wassermann test, negative. Mental attitude good, but somewhat nervous about the outcome of this birth because of two previous deliveries. B.p. 136/82.

Labor History: Patient admitted to hospital for induction of labor, having taken quinine and digitalis since June 25, as directed by Dr. Rucker. Membrane ruptured with uterine dressing forceps at 9:47. Pains began at 10:30 A. M. Duration of labor five hours, 50 minutes. Anesthetic: morphine gr. 1/6; sodium amytal, gr. 6, hyoscine, gr. 1/100; pentothal 750 mg. Local, with 1 per cent novocaine and adrenalin.



FIG. 4.—Result at three-and-a-half years.

GROUP III: REPAIR of DEFECT

Reported by	C.	S.	YEAR	SIZE OF DEFECT	TIME-LAG BIRTH TO OPERATION	RESULT WHEN REPORTED
1) HOGUE, W. P. CHARLESTON, W. VA.	N.	M.	1882	1" x 1 3/4"	1 1/2 HRS.	CHILD LIVING and NORMAL 8 YEARS OLD
2) CAFFIER, P. BERLIN	W.	M.	1929	6 3/4" diam.	BRIEF: (CONSERVATIVE TREATMENT)	CHILD LIVING and HEALED AFTER 3 MONTHS
3) GAMBLE, H. A. GREENVILLE, MISS.	W.	M.	1930	3 1/2" diam.	NONE	CHILD LIVING and NORMAL AFTER 7 MONTHS
4) WILLIAMS, C. RICHMOND, VA.	N.	F.	1930	3" diam.	2 DAYS	CHILD DIED, 12 HOURS LATER
5) DRY, F. M. ILLINOIS	W.	F.	1934	LARGE	BRIEF	CHILD DIED, SAME DAY
6) KOONS, F. W. KANSAS	W.		1934	2" diam.	X HOURS	CHILD DIED, 4 DAYS LATER
7) WATKINS, WAYNESBORO, VA.	W.	M.	1943	SLIT, 1" long	1/2 HOUR	CHILD LIVING and NORMAL AFTER 5 WEEKS
8) JOHNS, F. S. RICHMOND, VA.	W.	M.	1945	10 cm. long 11 cm. wide	1/2 HOUR	CHILD LIVING and NORMAL AFTER 3 1/2 YEARS
9) BENEDICT, S. C. ATHENS, GA.	W.	M.	1892	4" diam.	53 HOURS	CHILD LIVING and NORMAL AFTER 3 WEEKS

FIG. 5

for the abdominal defect. This was 11 cm. wide, 10 cm. long, extending from just below the xiphoid to some distance below and including the umbilicus. This large gastroschisis was entirely covered by a thin translucent veil-like membrane which had not been ruptured. Through the covered aperture the liver, gallbladder, stomach, colon and small intestines protruded above the surface of the abdomen.

The operation was carried out under general ether anesthesia. Local anesthesia would not have been suitable in this case, for which complete relaxation was essential.

The first procedure was to get the abdominal contents back inside the cavity, so that an attempt at closure could be made. At first, when the organs were forced back gently into what should have been their normal position, the baby would stop breathing. Hoping to improve this situation by exerting very gradual pressure, I put in silk ligatures one-half an inch back on the skin at the upper and lower ends of the defect. Then pulling the sides together very gradually, I attempted to close the opening. In doing this the folds of the unruptured peritoneum were left as a permanent over-all covering. The upper and lower part of the defect could be pulled together without too much tension. In the center, where the defect had been 11 cm. wide, a space at least 2.5 cm. across was left without closure. Adhesive strips were placed over the entire length of the "wound." A dressing was applied and the baby was returned to the nursery.

The postoperative course was uneventful, CO₂ and O₂ were given during the first night and following day. Lactose feedings were begun and retained. Normal saline was given subcutaneously and some diluted breast milk was given on the second postoperative day. On the fifth day he was put to the breast. Fifty cubic centimeters of plasma, (from his father's blood) were given on the 6th, 7th, 8th, 9th and 11th days. The baby's weight increased satisfactorily, and he left the hospital after 13 days, weighing 6 lbs. 5 oz. The entire strapping was kept on for about six weeks, or until there was complete granulation under it.

COMMENT.—In the above case report, three facts contributed to its successful result: (1) The case was reparable, *i.e.*, the organs were not entirely eventrated through the defect, and the abdominal cavity while shallow was nearly sufficient to contain them. (2) The defect though very extensive was covered by an unruptured peritoneum, and this covering was not injured or disturbed during the repair operation. (3) There was only a brief time-lag between delivery and surgical repair.

A careful delivery by a competent obstetrician is of utmost importance in all cases of reparable gastroschisis. The essential presence of an unruptured peritoneum depends upon such skilled and able handling. Equally important is the care that must be exercised during operation to avoid puncturing or tearing this thin peritoneal covering over the abdominal viscera. Meticulous care must be used in putting in the interrupted sutures to avoid any injury to the exposed peritoneum, in order to ensure an aseptic repair so far as the peritoneal cavity is concerned. As Williams states: Immediate operation, before this covering has become hard and friable, is also of primary importance.

In the application of interrupted, nonabsorbable ligatures, no attempt was made to freshen or free the borders of the defect before closure. They will heal without this additional surgery, which could well affect the mortality of such cases.

The occurrence of this congenital defect is rare, but, as shown in the literature, it does occur. And when it happens we must be prepared to take

care of it promptly and efficiently, with a minimum of surgical procedure. Delay or failure to operate is fatal even in the less serious cases.

This defect was further reinforced by Dr. William Moncure, Salisbury, N. C.

BIBLIOGRAPHY

- ** Aranow, H.: J. A. M. A., May 28, 1910.
- Ballantyne, J. W.: Quinquennium of Med. & Surg., 1906-1911, p. 38.
- * Barton: Times & Register, Philadelphia, 1889, xx, 178.
- ** Batalla: El Siglo Medico, V. 21, 1874.
- * Bax: Soc. Med. d'Amiens, Bull (1878-9) 1880, xviii, xix, 158-160.
- *** Benedict, S. C.: Medical Record, V. 41, March 5, 1892, p. 263.
- * Bernstein, P.: Archives of Pediatrics, V. 5, 1940.
- * Blake, F.: Lancet London, 1923, p. 976.
- ** Bott, S.: Lancet London, 1911, p. 1134.
- * Boylston: Boston Med. & Surg. J., 1837, 16, 382.
- * Brown, W.: Brit. Med. Journal, 1, p. 14, 1890.
- * Brymo, G.: J. Akush jensh. boliez. 1910, 24.
- ** Calder, J.: Med. Essays & Observations, Edinburg 1, 203, 1733.
- *** Caffier: Zentralblatt f. Gynak. v. 53, 2, 1929, pp. 2087.
- * Calorni: Lancet Bologna, 12, 1907.
- * Canton: Lancet London, 1849, 2, 266.
- Chapple, C. C., & Davidson, D. T.: Am. J. Pediatrics, 18, 483-493, Apr. 1945.
- Coe, H. E.: Rocky Mountain Med. J., 38, 630.
- * Cooper, P. R.: Brit. Med. J., 2, 687, Nov. 24, 1917.
- * Coxon, H. C.: British Med. Jour, Sept. 29, 1917.
- ** Crowther, B.: Lancet London, 1, May 18, 1878, 737.
- ** Das, K.: Proc. R. Soc. of Med. V. 1, 2, Apr.-July, 1908.
- * Denton, P.: Bull. Soc. Med. de la Suisse Rom. Lausanne, 23, 158, 1879.
- *** Dry, F. M.: Ill. Med. J. V. 65, 1934.
- * Eves, A.: Lancet London, 1844, 1, 463.
- ** Fletcher, M. A.: Med. Journal of Australia, April 7, 1928.
- ** Forsyth, C. B.: Jour. A. M. A. May 28, 1908.
- *** Gamble, H. A.: Sou. Med. & Surg. V. 25, 7, p. 771, 1930.
- * Genova, A.: Ann. Ostet, Milano, 45, 1923.
- * Gruber, G. B.: Zschr. u. Chir. 11, 51, 1922.
- * Hallett, C. H.: Edinburg M. & S. Jour. 1847, v. 48, 303.
- * Hawkins, V. J.: Northwest Lancet, 1892, xii, 70.
- * Hein, R.: Arch f. Path. Anat. Berlin, 1873, 48, 326.
- * Hess, E.: J. Uron. Baltimore, 1923, 10, 321-323.
- * Hirst, B. C.: Med. News, Feb. 23, 1895.
- * Hodge: Med. Times, Phila. 1870, 1, 324.
- * Hodges, R. M.: Am. J. Med. Soc. of Phila. 1854, n.s. 23, 394.
- *** Hogue, M. P.: Trans. Med. W. Va., 1987, 436-438.
- ** Hyde, C. L.: Archives of Pediatrics, Nov. 1930.
- * Imlach: Edinburg Med. Journal, v. xviii, 415-418, 1872-73.
- ** Johnston, J. A.: Cincinnati Lancet-Clinic, 1903 n.s. 31, 64.
- Keith: Brit. Med. J. 7, 435, March, 1932.
- Kermauner: Arch. f. Gynak. 75, 212, 1905.
- * Klautsch, A.: Centralbl. f. Alleg. Path. u. Path Anat. 6, 385, 1895.
- ** Kleine, O. O.: Arch. Gynak. 1928-29, 135.
- * Kleiner, R.: Mscher Geburtch Gunak. 1930, 84, 281.
- *** Koons, F. W.: J. Kansas Med. Soc. 35, 136-138, April, 1934.

- ** Kramarenko: Russkaya Meditsina 1888 Nr. 13, p. 202.
- ** Krauss, F.: Deutsche med. Wnschr. 7, Feb. 26, 1936.
- * Leavitt, F.: N. W. Lancet, Minneapolis, 1902 n.s. 22, 319.
- ** Lee, D. F.: Indiana Med. Jour. 1906-07, 25, 387.
- * Lindsay, J.: Trans. Glasgow Obst. & Gyn. Soc. 3, 233, 1902.
- Lippman, O.: Zentralbl. f. Gynak. 61, 516-524, Feb. 27, 1937.
- * Lockwood & Addison: Quart. Jour. Med. Sheffield, 7, 231, 1898-1899.
- * Macgill, H. M.: Lancett 2, 687, 1894.
- * Macmahon, J. R.: Lancet, 1898, 2, 686.
- * Magid, O. M.: Am. Jour. of Obst Gyn. 1921-22, 2, 446.
- * Maitland, H. S.: Jour. of New Jersey Med. Soc.
- McGuire, S.: Va. Semi. Medical Monthly, Nov. 22, 1912.
- * Mery: Hist. Acad. Roy. de sc. 1716 Paris.
- * Mills, T. W.: New Orleans, Jour. Med. 1869, 22, 789.
- * Mitchell: Brit. M. J. London, 1903, 1, 196.
- * Montgomery, D. W.: Pacific Med. & Surg. Jour. Western Lancet 1888, 1, 359.
- * Natale, C.: Medicina Kaunas, 9, 285, 1928.
- Neville, W. C.: Tr. Acad. Med. of Ireland, Dublin, 1883, 1, 359.
- * O'Farrell: Trad. Semena Med. Buenos Aires, 1903, x, 815.
- ** Ogle, J. H.: Tr. Path. Soc. London XV, 236, 1864.
- * Poloyas, S. H.: Am. J. of Obstetrics & Gyn. 1931, pp. 109-112
- * Pribram, E.: Archives of Pathology, V. 1927.
- ** Purdy, W. O. & Stofer, B. E.: Jour. Iowa State Med. Soc. Oct. 1934.
- Putz, T.: Geburtsch w. Frauenh. 1, 663.
- * Sandifort, E.: Acta Helvet. Basiliae, 1772, 7, 56.
- * Saxtorph: Acta red. Soc. Med. Hav'n, 1783, 1, 191.
- * Schebat, L.: Bull. Soc. d'Obst. et de Gynec. 26, 484-486, June 1937.
- * Scheibel, O.: Acta Obst. & Gynec. Scandinavian, 6, 329, 1927.
- * Schenck, S. B.: Am. Jour. of Obstetrics, 1919 V. 80.
- ** Schmidt, C. G.: N. Y. Med. Jour. 1900, 72, 710.
- * Schupmann, A.: J. g. Gebutsch. Leipzig, 1937, 16, 111.
- * Sewall, J. G.: N. Y. Jour. Med. 1854.
- * Sheldon, J. G. & Heller, H.: Jour. Missouri Med. Assoc. 1922, 19, 493.
- * Simon, C.: Gaz. de Hop. Paris, 1856, 19, 262.
- * Skeka & Stoesser: Am. Jour. Diseases of Children, Feb. 1927.
- * Stangl, E.: Archives f. Kilin. Chir. 37, 852, 1904.
- Sternberg & Politzer, Beitr. z. Path. Anat. u.z. Alleg. Path, 88, 150-152 Nov. 19, 31
- * Stephan, S.: Zsch. Geburt. u. Gynak, 1917-18, 80, 591.
- * Stroer, W. F. H.: Beitr. z. Path. Anat. u.z. Allg Path. 106, 302-15, 1942.
- * Szantroch, Z.: Virchows. Arch. f. Path. Anat. 278, 539, 1930.
- Taruffi, E.: Storia della Teratologia.
- ** Tate, M. A.: Cincinnati Lancet-Clinic, 1903, N.S. 51, 64 (V. Johnston, J. A.)
- ** Todd, G. B.: Lancet, London, 1895, 2, 142.
- Van Ruess: Dis. of New Born, p. 323-326, 1920.
- * Vandeusen, E. H.: Tr. Med. Soc. Penn. 1890, Phila. 1891, 26, 149.
- * Waldstein: Wein. Klin. Wehnsch. 1897.
- * Walton, E.: Rev. phot. d. hop de Paris, 1874, vii., 131.
- ** Watkins, D. E.: Va. Med. Monthly, Jan. 1943.
- *** Williams, C.: Surg. Clinics of North America, v. 30, 1930, 805.
- * Woodhouse, W. M.: Lancet 1897, 1, 443.

-
- * is Group I
 - ** is Group II
 - *** is Group III

GASTROSCHISIS

DISCUSSION.—DR. CARRINGTON WILLIAMS, Richmond, Va.: All these congenital abnormalities bring out a number of points of interest. Whether the theory of adherence of amnion to the peritoneum is correct I do not know, but it seems logical to think that, along with other abnormalities in the midline of the body, the trouble is due to failure of the mesodermal tissue to unite. Operability of these infants, of course, depends entirely on the degree of herniation of viscera through this thin layer and, unfortunately, in a great number of cases the liver is so large that closure is impossible. I feel responsible for the death of one child. You could look into the abdomen and see the various abdominal viscera. I made the mistake of putting off operation for 12 hours and, during that period, being a curiosity, it was viewed by a number of people and when it came to operation the membrane was greenish; and the child died of peritonitis after operation. Doctor Johns operated 30 minutes after birth and this demonstrates the most important thing, particularly around a medical school where everyone wants to see it. The rectus muscles in the baby I operated upon were intact, but widely separated. They should be brought together if the defect is not too great.

DR. HUGH A. GAMBLE, Greenville, Miss.: When I was asked by Doctor Johns to discuss this paper I felt there was little I could add and when I had read it I knew that there was practically nothing. I feel that the Association is to be congratulated on Doctor Johns' assembly of this complete bibliography of this rare condition. We do not know what causes it, but I have been inclined to agree that it is failure of union between the mesoblastic layers of the abdominal wall.

I have seen only one case 30 minutes after birth. The membrane covering the opening into the abdomen had ruptured and whenever the baby would cry the stomach and liver would pop out. This child had to be given a general anesthetic. It may be best, as Doctor Johns has suggested, not to disturb the translucent membrane. In the case I saw, the membrane had been ruptured and I excised it. The opening was closed by a modified Mayo operation; first, bringing the upper borders obliquely across the defect and, second, closing the remainder of the defect by suturing the lower border to the upper edges of the wound. It is impossible to use the overlapping flap as in the Mayo operation, as it is both impractical and impossible, because of the thinness of the abdominal wall, to dissect up flaps. The walls which are lined with peritoneum are sutured, peritoneum to peritoneum, with interrupted nonabsorbable material.

This child had primary union and an uneventful recovery. He is now 16 years of age, takes part in all sports and has had no complications, except possibly one, as a result of this congenital defect. Last summer while on a fishing expedition he was taken suddenly ill with an acute attack of appendicitis and was carried to a nearby city where an exploratory operation was performed. I have been told that the appendix was never located, and I have often thought that this was due to probable nonrotation of the large bowel, because the surgeon who performed the operation was an exceptionally capable man and there must have been some abnormality present to prevent the locating of the appendix.

In my opinion early treatment with closure of the defect is essential, because the longer one delays the more necrotic the covering membrane becomes and the greater the danger of infection. As someone has said, these cases should be taken from the delivery room to the operating room. If you fortunately get them shortly after birth it is remarkable how firm a wall one can get by simply suturing the peritoneal lining to peritoneum with a through-and-through nonabsorbable suture.

DR. H. M. SCHIEBEL, Durham, N. C.: I would like to add an additional case to Doctor Johns' series, which I happen to have had about 11 months ago and have not yet reported. It was entirely similar to the ones described—perhaps a little more like Doctor Gamble's case. The defect was five centimeters in diameter, but rose particularly high above the abdomen, so that almost all the right half of the liver, the gallbladder and a part of the duodenum were visible outside the abdominal cavity and covered by a thin translucent membrane. It was closed in layers with cotton sutures after dissecting away the membrane, as described by Dr. Gamble. The child was seen one-half hour after birth, and was operated upon immediately. Recovery was uneventful.

DR. WILLIAM B. MARBURY, Washington, D. C.: In reporting this case I feel a little like the country doctor whom Dr. Sandy Moore says you can always tell because he has his pockets filled with pencils, a little horse manure on his heels, and an interesting case to report.

My interesting case is one that I saw during the past year. This baby was born during the wee small hours of the morning—as most of them are—and I saw it in the forenoon along with the pediatrician and obstetrician. It had a large defect of the abdominal wall (omphalocele) and though we knew a repair was necessary we were not sure about the optimal time for operation. The pediatrician thought we should wait and build the baby up a little, but the obstetrician and I thought he should probably be operated upon as soon as possible. After consulting Ladd and Gross' book "Surgery in Infancy and Childhood," we learned that these cases should be removed from the delivery room to the operating room.

The defect in this case was about eight centimeters in diameter and one could look through the clear amniotic membrane and peritoneum as through a window, and see the liver and intestines on the inside. This condition changed after some hours and at the time of operation the membrane had become quite opaque. Also, in the hours that elapsed between birth and operation there was a definite increase in size. Each time the baby cried there was a protrusion which seemed to increase the hernia.

Under ether anesthesia, an incision was made in the skin about a quarter of an inch from the amniotic membrane. The sac and cord were removed and the umbilical vessels were tied off. The adhesions to the liver were fairly firm and caused some bleeding when they were freed. The skin and peritoneum were sutured with interrupted silk, with no effort to bring the fascia together.

Ladd and Gross warn against making the closure too tight, stating that it may embarrass respiration or cause pressure on the vena cava with circulatory disturbance. They report 22 cases, 12 of which died; two of these were not operated upon and both died. Many of these cases are associated with other congenital anomalies. This baby had, besides the omphalocele, two inguinal herniae. Except for being a rather difficult feeding case, when last seen he was doing very well.

This reminds me of something I heard in this Association a few years ago. The essayist said that the only way to kill a new-born baby was to cut its throat. I believe this was not meant to be taken too literally, but it does emphasize the fact that babies stand operation well, and there seems to be a definite biologic tendency to live and not to die.

DR. CHARLES HUGH MAGUIRE, Louisville, Ky.: In line with Doctor Johns' review of this subject, it is a relatively uncommon condition and, of course, surgically important. I have another case that could be reported but time does not permit. There is a technical point that has been brought out by Ladd and Gross in their splendid book, that has been very satisfactory in closure of the abdomen in infants after repair of diaphragmatic herniae or abdominal wall defects.

We had a youngster with almost complete absence of the left diaphragm, and the stomach, spleen, left lobe of the liver and a large part of the small bowel were in the left pleural cavity. We repaired the diaphragmatic defect with difficulty and, when an attempt was made to close the abdomen, there was so much tension that we knew it would probably break down our repair if the organs were replaced in the abdomen, and the abdominal wall sutured under tension. The skin was dissected up from the rectus sheaths for a distance of four to five centimeters laterally, and the skin flaps were approximated with interrupted silk sutures. No effort was made to close the rectus muscle, peritoneum, or rectus sheaths. The youngster was returned to bed and ten days later was brought back to the operating room; the skin silks removed; a few adhesions between the rectus muscle and the small bowel were freed and an easy closure of the abdomen in layers was accomplished.

DR. FRANK S. JOHNS, Richmond, Va. (closing): I want to emphasize two things which I think contributed to the successful repair of this case of gastroschisis. First, the surgical repair of the defect was carried out immediately. There was only one-half hour delay from birth to operation. Second, time was not wasted in an effort to

GASTROSCHISIS

undermine the skin around the defect. As seen in this case, healing will be complete by simple closure. To "freshen the edges" of the walls of the defect is to invite infection; and it is also possible that this unnecessary procedure may result in the further disaster of evisceration after operation.

Nineteen babies have been recorded in the literature who were normal in all respects except for a defect in the abdominal wall. All 19 died without any attempt made to repair the defect, and we can be sure that the majority of such cases are never reported. I would direct attention to this rare and reparable congenital anomaly. For these unfortunate but viable infants, an immediate and meticulous though simple surgical procedure is required.

GANGRENOUS SUPPURATIVE APPENDICITIS

FORTY-EIGHT CONSECUTIVE CASES WITH REMOVAL OF THE APPENDIX AND
COMPLETE CLOSURE OF THE WOUND, WITHOUT A DEATH

E. DUNBAR NEWELL, M.D.

CHATTANOOGA, TENN.

IN 1929, I wrote a paper, entitled "Peritoneal Drainage, with especial Reference to Drainage or Nondrainage Following Appendectomy when the Appendix is Ruptured." This paper was read before the Southern Surgical Association. There were 56 cases in all that I had operated upon individually. Twenty-three of this series of cases of suppurative appendicitis had free pus in the peritoneal cavity. I closed the peritoneal cavity without drainage and had no deaths. In 33 of these cases of suppurative appendicitis with free pus in the peritoneal cavity, I used drainage in the peritoneal cavity and had eight deaths. In eight of these peritoneal-drainage cases the appendix was not removed. Three of the eight deaths occurred where the appendix was not removed. This gives a mortality rate among these 33 cases, where drainage was used, of 24.2 per cent.

My observation at that time was: (1) that patients with peritoneal drainage had a longer convalescence, with a much longer stay in the hospital than patients without peritoneal drainage; (2) that the complications were more severe and more frequent where there had been peritoneal drainage than in cases without peritoneal drainage. At that time my rule for using or not using peritoneal drainage was to close the peritoneum without drainage if all necrotic tissue could be removed and all bleeding controlled; if I felt that I could not remove all the necrotic tissue without too much trauma and could not completely control bleeding without a gauze packing, then I used drainage.

In a paper that was read before the last meeting of the Southern Surgical Association, in Hot Springs, Virginia, by Dr. T. B. Aycock, of Baltimore, on "The Effects of Sulfonamides on the Mortality Rate in Acute Appendicitis," he reports on a survey of 1151 consecutive patients that were diagnosed acute appendicitis and were operated upon at the Baltimore City Hospitals, extending over a period from January, 1935, until May 1, 1944. Six hundred and fifty-one of this series were operated upon prior to June 19, 1940, with a resulting mortality rate of 5.2 per cent, and 500 were operated upon since June 19, 1940, with a resulting mortality rate of 1.2. Since 1940, sulfonamides have been used in the contaminated peritoneal cavity. Prior to June, 1940, no sulfonamides were consistently used either systemically or locally.

In reviewing my own cases since July 24, 1942, I have personally operated upon 202 cases of acute appendicitis with no deaths, and in which no sulfonamides were introduced into the abdominal cavity. During this same period I

* Presented by title before the Fifty-seventh Annual Session of the Southern Surgical Association December 4-6, 1945, Hot Springs, Virginia.

SUPPURATIVE APPENDICITIS

have operated upon 48 cases of acute suppurative appendicitis with free pus in the peritoneal cavity, with no deaths. In every instance of these suppurative appendicitis cases five grams of sulfanilamide powder were placed in the peritoneal cavity around the cecum and in the area where the appendix was removed. In 11 of the 48 cases penicillin was used in large doses. Whole blood transfusions were given frequently; no food was given by mouth for the first three days—the patients were given either blood transfusions or intravenous glucose solutions. In my absence, my assistant used penicillin in the abdominal cavity of one case. Several months later the patient developed intestinal obstruction and, at operation, I found a great mass of adhesions around the area where the penicillin had been introduced. The patient recovered from his second operation. In every instance, the appendix was removed, notwithstanding the fact that there was an abscess or not. No patient with a ruptured appendix was refused operation, regardless of his general condition or the length of time from the onset of his attack. In other words, I have operated upon every case of ruptured appendix that was referred to me, and have removed the appendix since July 24, 1942. Formerly, I did not remove the appendix from an abscessed cavity if it was difficult to remove it, but put in a drain and waited until later to remove the appendix. Since I have been using sulfanilamide with such apparently excellent results, I do not hesitate to remove the appendix even in the presence of an abscessed wall, where often it is difficult to remove the appendix; and in all but one case, no drainage was used, and in all the cases the abdominal wound was closed completely, in layers. The drainage case was one small soft rubber tissue drain placed in the lower end of the wound, but the wound was otherwise completely closed in layers. The patient was a doctor and before operation had insisted that I use a drain. This is the only case that developed a postoperative hernia. Formerly, I closed the peritoneum completely without drainage but did not close the muscle, fascia and skin until several days later. There was only one residual abscess, and this was opened and drained through the cul-de-sac.

In five of these cases the duration of the attack before operation was four to six days, and in a large majority of the series the patients were operated upon on the third day after the onset of the attack. The educational program which we have conducted in this area, against the use of purgation in patients having abdominal pain, has evidently been successful, as very few of these cases had had violent purgation. Formerly, most of our cases from the rural areas had had violent purgation before they came to the hospital. I think that the absence of violent purgation probably has been an important factor in lowering the mortality rate of my operative suppurative appendicitis cases.

AN INVESTIGATION OF THE RÔLE OF CHEMOTHERAPY IN WOUND MANAGEMENT IN THE MEDITERRANEAN THEATER*

CHAMP LYONS, M.D.

NEW ORLEANS, LA.

IN A PREVIOUS REPORT¹ which summarized the early surgical experience with penicillin in the United States Army the inability of sulfonamides² and penicillin³ to sterilize dead tissue and sequestra was established. It was concluded that a program of whole blood replacement and systemic penicillin therapy made it safe and practical to undertake surgical operations *at a time of election* in the management of wounds with established infection. The elective operation was limited at first to excision of devitalized tissue and removal of sequestra ("wound revision"). Primary closure after "wound revision" for established infection was contradicted by the observed incidence of anaerobic cellulitis. The wounds had to be left open to prevent the growth of proteolytic anaerobes in residual blood clots and tissue devitalized by surgical trauma and ligature. Even these open wounds were not entirely free from suppuration in spite of continued systemic penicillin therapy with or without additional local applications of high concentrations of the drug. The etiologic organisms in the suppuration of open wounds were found to be *Ps. aeruginosa* (pyocyanea) and *B. proteus*. The infection was clinically identical with the "injury necrosis"⁴ and the "gram-negative pus"⁵ of other observers. It was found that repeated local dressings increased the intensity and the incidence of gram-negative bacillary infection, but such infection did not preclude successful secondary closure by suture or skin graft ("reparative surgery").^{1, 6, 7, 8}

At this stage of the investigation the Surgical Consultants Division of the Surgeon General's Office arranged for the overseas exploitation of the possibilities of the reparative program of wound management. Indecision as to the ultimate success of this program prompted a thorough investigation of the whole problem of wound suppuration. It is the purpose of this report to outline the observations and conclusions of the program as undertaken in the Mediterranean Theater.

An unusual opportunity for the study of wounds of the extremity was afforded by the winter campaign in Italy during the early months of 1944. Casualties were received in well-established Base Hospitals located at a relatively short distance behind two static Combat Zones. The vicissitudes of evacuation were fairly constant and hospital organization became standardized on a semipermanent basis. The proximity of the Base Section in Naples to

* An abstract of a report in the Essential Technical Medical Data, Mediterranean Theater of Operations, October, 1944. Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

Fifth Army hospitals in the Forward Area provided an opportunity for direct exchange of information between Base surgeons and Forward surgical groups responsible for the care of a particular patient.

In the Cassino sector the fighting was in mountainous terrain. The weather was cold and wet. Casualties were transported by litter relays down the mountains to Clearing Stations for *triage* and transportation to Field and Evacuation Hospitals. Evacuation from Forward Hospitals to the Base Section was by ambulance and hospital train.

In the Anzio sector combat troops lived in fox-holes on a coastal plane. The weather was wet but less severe than in the mountains. Forward Hospital facilities were within the trajectory of heavy artillery fire and subject to danger from stray shells and air raids. It was necessary for these installations to be "dug in" to a depth of four to six feet. Evacuation to the Base Section was by boat (often LST) and sometimes proved a rigorous experience.

One milliliter "booster" doses of tetanus toxoid were given to all casualties without apparent exception. First aid administration of sulfanilamide powder locally and of sulfadiazine orally at the time of wounding was irregular. On the other hand, all except the most trivial casualties received 4 Gm. of sulfadiazine daily during the first few days after initial surgical management of the wound. Local implantation of sulfanilamide in excised wounds was widely but not universally practiced. In Base Section Hospitals oral sulfonamide therapy was reserved for the indication of established sepsis. Inspection of wounds on open wards without gloves or masks was common practice. Sulfanilamide powder was dusted into wounds at the conclusion of such dressings in many, but not all, hospitals.

There can be little question that there was the usual seasonal increase in the incidence of infection during January, February and March, 1944. Hemolytic streptococcal infection tended to be locally necrotizing rather than invasive.

BACTERIOLOGIC INVESTIGATIONS*

The routine taxonomic classification of all bacteria in war wounds is admittedly an impossible task.⁹ However, it was felt that complete bacteriologic study of a few wounds was essential to any analysis of wound suppuration. Details of the technical procedures are reported elsewhere.^{10, 11} A single wound was selected for study in each of 36 patients. Twenty-seven wounds were grossly infected and nine clinically "clean." The time from injury to first culture varied from two to 45 days. Approximately seven months were required for completion of this bacteriologic study.

A survey of this sort must of necessity remain incomplete. At least two strains of fusobacteria were recognized in smears or early cultures and were lost on subculture. No spirochetes were recognized. Other bacteria were so

*The bacteriologic laboratory was under the immediate direction of Lt. Robert Rustigian, Sn.C., A.U.S., to whom the greatest credit is due for accomplishment of this phase of the study.

TABLE I

I. <i>Streptococcus</i>:		
A. Beta hemolytic:		
1. Lancefield group A.....		4
2. Lancefield group C.....		1
3. Strains "lost" in stock culture.....		2
B. Alpha hemolytic.....		1
C. Nonhemolytic:		
1. Enteric group:		
a. Aerobic.....		13
b. Micro-aerophilic.....		9
2. Undifferentiated group:		
a. Aerobic:		
(1) Simple.....		5
(2) Fastidious.....		1
b. Micro-aerophilic:		
(1) Simple.....		3
(2) Fastidious.....		8
c. Anaerobic:		
(1) Proteolytic.....		5
(2) Nonproteolytic.....		4
II. <i>Staphylococcus</i>:		
A. Hemolytic:		
1. <i>Staph. aureus</i>		13
2. <i>Staph. albus</i>		0
B. Nonhemolytic:		
1. <i>Staph. aureus</i>		1
2. <i>Staph. albus</i>		3
3. <i>Staph. (nonpigmented)</i>		2
III. <i>Micrococcus</i>:		
A. Aerobic.....		1
B. Microaerophilic.....		14
C. Anaerobic:		
1. Proteolytic.....		3
2. Nonproteolytic.....		18
IV. Aerobic gram-negative bacillus:		
A. <i>Proteus</i> :		
1. <i>Pr. vulgaris</i>		1
2. <i>Pr. mirabilis</i>		1

TABLE I—(Continued)

B. <i>Pseudomonas</i> :		
1. <i>Ps. aeruginosa</i> (pyocyanea).....		4
C. Coliform bacteria:		
1. <i>Aerobacter</i>		8
2. <i>Escherichia</i>		2
D. Paracolon bacteria:		
1. Paracolon <i>Aerobacter</i>		4
2. Paracolon <i>Escherichia</i>		2
E. Unidentified bacteria:		
1. Mucoid.....		3
V. <i>Clostridium</i> :		
A. Toxigenic:		
1. <i>Cl. perfringens</i> (welchii).....		7
2. <i>Cl. novyi</i> (oedemaliensis).....		2
3. <i>Cl. septicum</i>		2
4. Unidentified.....		1
B. Nontoxigenic:		
1. <i>Cl. sporogenes</i>		22
2. <i>Cl. putrificus</i> group.....		8
3. <i>Cl. tertium</i>		6
4. <i>Cl. bifementans</i>		1
5. <i>Cl. sphenoides</i>		1
6. <i>Cl. capitonalis</i>		1
7. Unclassified:		
a. Subterminal spores:		
(1) Proteolytic.....		2
(2) Nonproteolytic.....		1
b. Terminal spores:		
(1) Proteolytic.....		1
(2) Nonproteolytic.....		3
VI. Miscellaneous:		
A. <i>Bacteroides</i> :		
1. <i>B. melaninogenicum</i>		3
B. <i>Actinomyces</i> :		
1. Anaerobic.....		4
C. Diptheroids:		
1. Aerobic.....		6
2. Anaerobic.....		2
D. <i>Bacillus</i>		3
E. <i>Bacteriaceae</i>		2
Total cultures.....		214

TABLE II

OBLIGATORY ANAEROBES ISOLATED FROM WAR WOUNDS

Culture	No. of Cultures
1. <i>Clostridium</i>	58
2. <i>Micrococcus</i>	21
3. <i>Streptococcus</i>	9
4. <i>Actinomyces</i>	4
5. <i>B. melaninogenicum</i>	3
6. Diphtheroids.....	2
Total.....	97, or 45.3% of total

TABLE III

MICRO-AEROPHILIC BACTERIA ISOLATED FROM WAR WOUNDS

Culture	No. of Cultures
1. <i>Micrococcus</i>	14
2. Undifferentiated streptococcus.....	11
3. Enteric streptococcus.....	9
Total.....	34, or 15.9% of total

TABLE IV

AEROBES OR FACULTATIVE ANAEROBES ISOLATED FROM WAR WOUNDS

Cultures	No. of Cultures
1. Streptococcus:	
a. Beta hemolytic.....	7
b. Alpha hemolytic.....	1
c. Enteric.....	13
d. Undifferentiated.....	6
2. Staphylococcus:	
a. <i>Aureus</i>	14
b. <i>Albus</i>	3
c. Nonpigmented.....	2
3. <i>Micrococcus</i>	1
4. <i>Proteus</i> :	
a. <i>Vulgaris</i>	1
b. <i>Mirabilis</i>	1
5. <i>Pseudomonas aeruginosa</i>	4
6. <i>Aerobacter</i> :	
a. Paracolon <i>Aerobacter</i>	4
7. <i>Escherichia</i> :	
a. Paracolon <i>Escherichia</i>	2
8. Diphtheroids.....	6
9. <i>Bacillus</i>	3
10. <i>Bacterium</i>	2
11. Unidentified gram-negative bacilli.....	3
Total.....	83, or 38.8% of total

CHEMOTHERAPY IN WOUND MANAGEMENT

fastidious in their metabolic requirements as to preclude effective study after isolation. In all, there were 214 pure cultures of bacteria isolated from the 36 wounds (Table I) about three-fifths of which were obligatory or preferential anaerobes (Tables II and III). Only two-fifths of the cultures were aerobes or facultative anaerobes (Table IV). Listed in order of frequency, the predominant species were the *Clostridium* (58 cultures), the *nonhemolytic*

TABLE V
THE INCIDENCE OF POTENTIALLY INVASIVE OR TOXIGENIC BACTERIA—TRUE PATHOGENS

Bacteria	Cultures	
	No.	% of Total
1. Toxigenic <i>Clostridium</i>	12	5.6%
2. Coagulase-positive <i>Staphylococcus</i>	11	5.1%
3. <i>Beta hemolytic Streptococcus</i>	7	3.3%
Total.....	30	14.0%

TABLE VI
PROTEOLYTIC ACTIVITY OF STREPTOCOCCUS

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H ₂ S	Gas
<i>Beta hemolytic Streptococcus</i> :							
Group A—4.....	0	0	0	+	0	0	0
Group C—1.....	0	0	0	+	0	0	0
<i>Enteric Streptococcus</i> :							
21.....	0	0	0	0	0	0	0
1.....	0	+(Trace)	+	0	+	0	0
<i>Nonhemolytic Streptococcus</i> :							
Aerobic—5.....	0	0	0	0	0	0	0
Micro-aerophilic:							
4 simple.....	0	0	0	0	0	0	0
7 fastidious.....	0	0	0	0	0	0	0
Anaerobic:							
4.....	0	+	+	0	+	+	0
1.....	0	0	0	+	0	+	+
4.....	0	0	0	0	0	0	0

Streptococci (48 cultures) and the micrococci (36 cultures). *Clostridium sporogenes* was isolated 22 times and was the commonest single bacterial type.

The species known to be potentially invasive or toxigenic represented only 14 per cent of the total cultures isolated (Table V). Only four of the 27 grossly infected wounds presented any clinical evidence of invasive infection or specific toxemia. In three instances of gross infection none of the potential true pathogens were recovered. It seemed reasonable to conclude that the biologic emphasis in the further study of the isolated bacteria should identify the factors most likely to be concerned with the process of septic liquefaction characteristic of wound suppuration.

Although bacteriologic phraseology permits the designation of bacteria as "wound pathogens," there has been no precise definition of the cardinal attributes of such organisms. Common practice for the denomination of wound

pathogens is based upon a consideration of the essential metabolic substrate. Wound pathogens differ from true pathogens in that they are lacking in those qualities permitting a direct attack upon living tissue. Essential metabolites for growth of wound pathogens are secured in the process of septic decomposition of devitalized tissue, blood clot and wound exudate. A secondary consequence of this septic decomposition is local necrosis of living tissue exposed to the products of suppuration. Especially vulnerable in the recent wound are the relatively avascular collagenous tissues of tendon, fascia, cortical bone and cartilage. The distinction between invasive or toxigenic necrosis of living tissue and the septic decomposition of devitalized tissue has been emphasized by the introduction of chemotherapeutic agents for the control of invasive infection. There is an increasing acceptance of the capacity to digest animal protein as the distinctive attribute for identification of "wound pathogens."^{1, 12, 13, 14}

The proteolytic capacities of the bacterial cultures were tested *in vitro* by inoculation of pure cultures into mediums containing different protein substrates. Muscle protein, serum, casein, fibrin, gelatin (modified collagen) and amino-acid mixtures were employed. The results of these tests are recorded in Tables VI, VII, VIII and IX.

The proteolytic activity of the streptococci is summarized in Table VI. The *beta hemolytic Streptococci* were typically fibrinolytic. Hyaluronidase activity was not tested because of technical difficulties and the desire to emphasize the locally necrotizing rather than the invasive attributes of the bacteria. The enterococci, with one exception, and the aerobic and *micro-aerophilic nonhemolytic Streptococci* were inert. Five of the nine cultures of *anaerobic nonhemolytic Streptococci* showed some degree of proteolysis. Thus, 41 of the 47 cultures of *nonhemolytic Streptococci* failed to qualify as proteolytic bacteria.

The staphylococcal cultures revealed a wide range of individual variation (Table VII). The coagulase test did not conform to the proteolytic tests. Of ten coagulase-positive *Staph. aureus* strains, only seven were gelatinolytic and three of nine coagulase-negative cultures were gelatinolytic. Obviously, there is need for further study to determine the relative merits of the coagulase test and gelatin liquefaction in the evaluation of wound pathogenicity for staphylococcal cultures.

Only two of the 21 cultures of anaerobic micrococci were gelatinolytic. Five cultures showed limited digestion of amino-acids. The *micro-aerophilic Micrococci* failed to grow in simple gelatin or amino-acid medium. As a group, the Micrococci appeared relatively unimportant as wound pathogens.

The four anaerobic cultures of *Actinomyces* liquefied gelatin and produced hydrogen sulfide in amino-acid medium (Table VII).

The *Clostridium* cultures are presented in order of decreasing proteolytic activity in Table VIII. *Cl. sporogenes* was the only bacterial type characterized by constant digestion of all test substrates by all cultures. This observation is made more significant by the recognition of *Cl. sporogenes*

CHEMOTHERAPY IN WOUND MANAGEMENT

TABLE VII
PROTEOLYTIC ACTIVITY OF STAPHYLOCOCCUS, MICROCOCCUS AND ACTINOMYCES

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids		Coagulase
						H ₂ S	Gas	
<i>Staphylococcus</i> :								
1. <i>Aureus</i> :								
2.....	0	0	0	P(weak)	+	0	0	+
1.....	0	0	0	P(weak)	+	0	0	0
1.....	0	0	0	P(weak)	0	0	0	+
2.....	0	0	0	P(weak)	0	0	0	0
5.....	0	0	0	0	+	0	0	+
2.....	0	0	0	0	0	0	0	+
1.....	0	0	0	0	0	0	0	0
2. <i>Albus</i> :								
1.....	0	0	0	0	+	0	0	0
2.....	0	0	0	0	0	0	0	0
3. Nonpigmented:								
1.....	0	0	0	0	+	0	0	0
1.....	0	0	0	0	0	0	0	0
<i>Micrococcus</i> :								
1. Microaerophilic.....	0	0	—	0	n.g.	n.g.	n.g.	—
2. Anaerobic:								
2.....	0	0	—	0	+	+	0	—
1.....	0	0	—	0	0	+	+	—
2.....	0	0	—	0	0	+	0	—
2.....	0	0	—	0	0	0	+	—
14.....	0	0	—	0	0	0	0	—
<i>Actinomyces</i> :								
4.....	0	0	0	0	+	+	0	—

P(weak) = atypical partial dissolution of clot.

n.g. = no growth.

— = not tested.

TABLE VIII
PROTEOLYTIC ACTIVITY OF CLOSTRIDIUM

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H ₂ S	Gas
<i>Sporogenes</i>22	+	+	+	+	+	+	+
<i>Putrificus</i> group.....8	+ or 0	+	+	+ or 0	+	+	0
<i>Bifementans</i>1	0	+	+	—	+	+	+
<i>Capitovialis</i>1	0	0	+	0	+	+	+
<i>Perfringens</i>7	0	0	0	± or 0	+	+	+
<i>Novyi</i>2	0	0	0	±	+	+	+
<i>Septicum</i>2	0	0	0	±	+	0	+
<i>Tumefaciens</i>1	0	0	0	±	0	+	+
<i>Tertium</i>6	0	0	0	0	0	+	+ or 0
<i>Sphenoides</i>1	0	0	0	0	0	+	0
Unidentified nontoxigenic:							
1. Subterminal spores—2	0	0	+	0	+	+	+
2. Subterminal spores—1	0	0	0	0	0	+	0
3. Terminal spores—1	0	0	0	+	+	+	0
4. Terminal spores—3	0	0	0	0	0	+	0

+ or 0 = strain inconsistencies.

— = no test.

± = irregular results—positive and negative reactions obtained with each of several strains.

as the most frequent single bacterial type recovered from this series of war wounds. The *Cl. putrificus* group and *Cl. bifermentans* are only slightly less active and with *Cl. sporogenes* constitute the actively proteolytic members of the *Clostridium* group. Taxonomic emphasis upon the saccharolytic properties of *Cl. perfringens*, *Cl. novyi* and *Cl. septicum* has led to disregard of their proteolytic characteristics. These potentially toxigenic *Clostridia* have a greater proteolytic activity than the staphylococci and in this series were most frequently present in their alternative rôle of wound pathogens. Among the identified *Clostridium* types only *Cl. tertium* and *Cl. sphenoides* were unable to break down any of the test proteins.

B. melaninogenicum grows very slowly but has well-established proteolytic ability and is recognized as an organism associated with local tissue decomposition.¹⁵

Table IX is chiefly of interest in that it confirms the slightly greater proteolytic activity of *Proteus* as compared with *Ps. aeruginosa* (pyocyanea). Among the other aerobic gram-negative bacilli only the *para-aerobacter*¹⁶ cultures were regularly gelatinolytic. Only five of 21 cultures of aerobic gram-negative bacilli other than *Proteus* or *Pseudomonas* showed proteolytic activity.

Within the concept of denomination of potential wound pathogens on the basis of proteolysis observed with pure cultures, it is practical to identify certain bacterial groups as important in wound suppuration. All the true pathogens of the *Clostridium*, *Staphylococcus* and *Streptococcus* groups possess biologic activity consistent with alternative designation as simple wound pathogens. Of importance in this regard, is the recently observed enhancement of streptococcal proteolysis by serum lysate.¹⁷ Other bacteria, lacking invasiveness and toxigenicity, appear at present to be important only as wound pathogens: *Clostridium* of the *sporogenes*, *putrificus* and *bifermentans* groups; aerobic gram-negative bacilli of the *Proteus*, *Pseudomonas* and *para-aerobacter* groups; certain cultures of *Staphylococcus* and anaerobic nonhemolytic *Streptococcus*; anaerobic *Actinomyces* and *B. melaninogenicum*.

Other bacteria had little or no enzymic activity for the protein substrates tested. No proteolysis was observed with the cultures of *Micrococci*, enteric *Streptococci*, nonhemolytic *Streptococci* and gram-negative bacilli of the coliform and *para-escherichia* groups. A lytic effect on amino-acids was demonstrated for *Cl. tertium*, *Cl. sphenoides* and about one-third of the cultures of anaerobic micrococci. For analytical purposes these bacteria have been classified as "commensal" to designate their inability to initiate proteolysis in the process of septic decomposition. Such classification does not deny these organisms an important place as synergists in the ultimate liquefaction of wound proteins. It does signify their preoccupation with simpler nitrogenous substrates appearing as intermediary catabolites in the process initiated by the enzymes of wound pathogens.

One purpose of the attempted designation of wound pathogens was to

CHEMOTHERAPY IN WOUND MANAGEMENT

establish a basis for a study of the penicillin sensitivities of the various bacteria important in wound suppuration. Details of the sensitivity tests are recorded in Tables X, XI and XII. A more exhaustive consideration of this phase of

TABLE IX
PROTEOLYTIC ACTIVITY OF BACILLARY GRAM-NEGATIVE BACTERIA

Bacterial Cultures	Muscle	Serum	Casein	Fibrin	Gelatin	Amino-acids	
						H ₂ S	Gas
<i>B. melaninogenicum</i>3	0	+	—	—	+ or 0*	—	—
<i>Proteus</i>2	0	+	+(weak)	P(weak)	+	+	0
<i>Pseudomonas</i>4	0	+	+(weak)	0	+	0	0
Coliform bacilli:							
1. <i>Aerobacter</i>1	0	0	0	0	+	0	0
7	0	0	0	0	0	0	0
2. <i>Escherichia</i>2	0	0	0	0	0	0	0
Paracolon bacilli:							
1. <i>Para-aerobacter</i>4	0	0	0	0	+	0	0
2. <i>Para-escherichia</i>2	0	0	0	0	0	0	0
Unidentified.....3	0	0	0	0	0	0	0

P(weak) = atypical partial dissolution of clot.

+ or 0 = strain inconsistencies.

— = not tested.

* = taken from Prevot, A. T.—"Manual de Classification et de determination des Bacteries Anaerobies"—Monograph de L'Institute Pasteur, 1940, Masson et Cie, Paris.

TABLE X
PENICILLIN SENSITIVITY OF STREPTOCOCCUS

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resistant Strains	Total Strains Tested
	.025	.05	.1	.25	.5	1	2	5		
<i>Beta hemolytic Streptococcus:</i>										
Group A.....4									0	4
Group C.....1									0	1
<i>Enteric Streptococcus:</i>										
Gelatinolytic.....									1	1
Non-gelatinolytic.....						1	4		16	21
Total.....						1	4		17	22
<i>Nonhemolytic Streptococcus:</i>										
Aerobic:										
Simple.....1			2						0	3
Fastidious.....1									0	1
Micro-aerophilic:										
Simple.....1			1		1				0	3
Fastidious.....3		2	2						1	8
Anaerobic:										
Proteolytic.....4			1						0	5
Nonproteolytic.....			1			1			0	2
Total.....10		2	7		1	1			1	22

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

the study is available elsewhere.^{10, 11} The important implications of the observations are apparent in Table XIII. Although over 90 per cent of the cultures isolated in this series were gram-positive, not all of these were fully

sensitive to penicillin. Among the true pathogens the single completely resistant culture was a staphylococcus. Among the wound pathogens, resistant cultures included *Proteus*, *Pseudomonas*, *para-aerobacter*, several cultures of

TABLE XI
PENICILLIN SENSITIVITY OF STAPHYLOCOCCUS, MICROCOCCUS AND ACTINOMYCES

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resistant Strains	Total Strains Tested
	.025	.05	.1	.25	.5	1	2	5		
<i>Staphylococcus aureus</i> :										
Coagulase—positive:										
Gelatinolytic.....		3	2						1	6
Nongelatinolytic.....		1	3						0	4
Coagulase—negative:										
Gelatinolytic.....									1	1
Nongelatinolytic.....			1			1			0	2
<i>Albus</i>		3							0	3
Nonpigmented.....		2							0	2
Total.....		9	6			1			2	18
<i>Micrococcus</i> :										
Micro-aerophilic.....	4	6	1	1	2				0	14
Anaerobic:										
Proteolytic.....	2					1			0	3
Nonproteolytic.....	11					1	1		0	13
Total.....	17	6	1	1	2	2	1		0	30
<i>Actinomyces</i>	3								0	3

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

TABLE XII
PENICILLIN SENSITIVITY OF CLOSTRIDIUM

Bacterial Cultures	Units/cc. Penicillin for Inhibition								Resistant Strains	Total Strains Tested
	.025	.05	.1	.25	.5	1	2	5		
<i>Novyi</i>	2								0	2
<i>Septicum</i>	2								0	2
<i>Putrificus</i> group.....	7	1							0	8
<i>Tumefaciens</i>		1							0	1
<i>Bisfermentans</i>			1						0	1
<i>Capitovialis</i>				1					0	1
<i>Perifringens</i>				4	3				0	7
<i>Sporogenes</i>				2	8	8	4		0	22
<i>Tertium</i>						1	2		0	3
<i>Sphenoides</i>									1	1
Unidentified:										
Subterminal spores.....					3				0	3
Terminal spores.....		4							0	4
Total.....	11	6	1	7	14	9	6		1	55

"H" strain of *Staph. aureus* required 0.05 units/cc. penicillin for inhibition.

Cl. sporogenes, a few cultures of the staphylococci and, by inference, *B. melaninogenicum*. These bacteria emerge as the groups resistant to presently available chemotherapeutic agents in wound suppuration. Other bacteria, in-

CHEMOTHERAPY IN WOUND MANAGEMENT

cluding many penicillin-resistant types, were in the group established as commensal.

TABLE XIII
CORRELATION OF PATHOGENICITY AND PENICILLIN SENSITIVITY

Culture	True Pathogen	Wound Pathogen	Commensal	Penicillin Sensitivity*
<i>Staphylococcus</i>	+	+	+	0.05—Resistant
<i>Hemolytic Streptococcus</i>	+	+	0	0.025
<i>Clostridium</i> :				
1. <i>Novyi</i>	+	+	0	0.025
2. <i>Septicum</i>	+	+	0	0.025
3. <i>Perfringens</i>	+	+	0	0.25—0.5
4. <i>Putrificus</i>	0	+	0	0.025—0.05
5. <i>Bisfermentans</i>	0	+	0	0.1
6. <i>Sporogenes</i>	0	+	0	0.25—2.0
7. <i>Tertium</i>	0	0	+	1.0—2.0
8. <i>Sphenoides</i>	0	0	+	Resistant
<i>Streptococcus</i> :				
1. Anaerobic proteolytic.....	0	+	0	0.025
2. Other anaerobic.....	0	0	+	0.1—2.0
3. Nonhemolytic.....	0	0	+	0.25—Resistant
4. Enteric.....	0	0	+	1.0—Resistant
<i>Micrococcus</i>	0	0	+	0.025—2.0
<i>Actinomyces</i>	0	+	0	0.025

*Sensitivity expressed in units/ml. required for inhibition of growth.

TABLE XIV
INFECTED WAR WOUNDS OF THE UPPER EXTREMITY

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
1.	33 days	S. P.	Acute cellulitis	<i>Hem. Strept.</i> (gr. A) <i>Staph. aureus</i>		<i>Nonhem. Strep.</i>
2.	9 days	C. F.	Gangrenous erysipelas	<i>Hem. Strept.</i> (gr. ?)	<i>Pseudomonas</i> <i>Aerobacter</i>	Enteric <i>Strept.</i>
3.	17 days	C. F.	Wound suppuration	<i>Cl. perfringens</i> <i>Staph. aureus</i>	<i>Cl. bisfermentans</i> <i>Micrococcus</i> (anaer.) <i>Clostridium</i> (unident.)	<i>Cl. sphenoides</i> <i>Clostridium</i> (unident.) Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) <i>Diphtheroid</i> (anaer.)
4.	12 days	S. P.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Nonhem. Strept.</i>
5.	10 days	S. P.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Actinomyces</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Nonhem. Strept.</i> <i>Nonhem. Strept.</i> (micro-aer.) <i>Diphtheroid</i>

In this and subsequent tables:

- S. P. =soft-parts.
- C. F. =compound fracture.
- Unident. =unidentified.
- Anaer. =anaerobic.
- Micro-aer. =micro-aerophilic.

These observations establish the fact that there are several wound pathogens commonly present in wounds and resistant to chemotherapy. This is in addition to the clinical evidence that no available therapy can prevent the

septic decomposition of devitalized tissue in an open wound. On this basis it is argued that presently available chemotherapy can affect the problem of wound sepsis only through control of the invasive component of the infection. Other methods are mandatory for the control of local suppuration.

It may be stated that *the nutritional pabulum of wound protein is of far greater clinical importance than the taxonomic classification of the bacterial contaminants concerned with its septic decomposition.* The protein of devital-

TABLE XV
INFECTED WAR WOUNDS OF THE LOWER LEG

No.	Age of Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
				True Pathogens	Wound Pathogens	Commensals
6.	25 days	C. F.	Erysipelas and acute cellulitis	<i>Hem. Strept.</i> (gr. A)		<i>Aerobacter</i> <i>Micrococcus</i> <i>Micrococcus</i> (anaer.) <i>Diphtheroid</i> (anaer.)
7.	19 days	C. F.	Wound suppuration	<i>Staph. aureus</i>		<i>Aerobacter</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) Diphtheroid
8.	25 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>B. melaninogenicum</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Micrococcus</i> <i>Micrococcus</i> (micro-aer.) <i>Micrococcus</i> (anaer.)
9.	24 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Para-aerobacter</i> <i>Actinomyces</i> <i>B. melaninogenicum</i>	<i>Cl. tertium</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (2) <i>Nonhem. Strept.</i> (anaer.) <i>Micrococcus</i> (anaer.)
10.	22 days	C. F.	Wound suppuration	<i>Cl. novyi</i> <i>Cl. perfringens</i> <i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Cl. tertium</i> <i>Aerobacter</i> <i>Para-escherichia</i> <i>Nonhem. Strept.</i> Enteric <i>Strept.</i>
11.	29 days	C. F.	Wound suppuration		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Para-aerobacter</i>	<i>Nonhem. Strept.</i> (micro-aer.) <i>Bacillus</i> Diphtheroid
12.	28 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. C)	<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>B. melaninogenicum</i> <i>Nonhem. Strept.</i> (anaer.)	<i>Cl. tertium</i> <i>Micrococcus</i> (anaer.)

ized tissue affords an acceptable substrate for growth of anaerobic wound pathogens. Wound exudate protein affords a nutritional pabulum for growth of aerobic wound pathogens. Lister gave especial emphasis to excision of devitalized tissue as the means of controlling anaerobic infection.^{18, 19, 20} Also well-recognized in listerian philosophy was the fact that *the control of wound exudation is as important as the excision of dead tissue in the surgical management of contaminated or infected wounds.*

CLINICAL CONSIDERATIONS

Tables XIV, XV, XVI, and XVII correlate the important clinical and bacteriologic features of 26 grossly infected wounds. *Beta hemolytic Streptococci* were recovered from seven wounds (Nos. 1, 2, 6, 12, 14, 17, 18), but in only three wounds (Nos. 1, 2, 6) was there clinical evidence of the invasive or toxigenic pattern of streptococcal infection. Toxigenic *Clostridium* were present in seven wounds (Nos. 3, 10, 15, 16, 17, 19, 23) but in only one patient (No. 16) was there clinical evidence of toxemia. In three wounds (Nos. 11, 22, 26) there were no demonstrable true pathogens. In three wounds (Nos. 1, 6, 7) there were no demonstrable wound pathogens. In 19 wounds (Nos. 2-5, 8-12, 16-26) there were wound pathogens known to be relatively or completely resistant to penicillin. All these infections developed in spite of sulfonamide therapy. The high incidence of *Cl. sporogenes*, particularly in septic arthritis, is noteworthy.

In the management of these wounds, dead tissue and sequestra were removed surgically under the protection of systemic penicillin therapy. The wounds were left open and dressed with pressure and splints to control wound exudation. It had already been learned that primary closure of excised infected wounds ran the risk of anaerobic cellulitis.¹ The clean surgical appearance of the wound three to ten days later was used as the criterion of absence of infection. The first subsequent dressing of the wounds was done in the operating room with adequate facilities to perform secondary operations. "Clean" wounds were closed immediately by secondary suture or skin grafting. "Dirty" wounds were subjected to further excision of tissue devitalized by previous excision or by subsequent infection. Systemic penicillin was used throughout the period of treatment until the danger of impending or established invasive infection was past. No local chemotherapy was used. The successful management of these wounds, without endangering life or limb, has been recorded in detail.¹⁰

Table XIII summarizes the essential bacteriologic and clinical data on ten patients injured by high explosive shell fragments. All received systemic sulfonamide therapy after initial surgical treatment. The original postoperative dressings were changed for the first time in the operating room of the Base Section Hospital. Clinical appearance of the wound dictated further excision of dead tissue or a reparative surgical procedure.

Cases 27, 28, 29 and 30 were clean soft-part wounds. They were closed by secondary suture or skin grafting at the time of the first change of dressing. No chemotherapy was given, and the wounds healed without infection. Wound cultures were obtained from the entire blood clot and swabs of the wound. No invasive or toxigenic bacteria or wound pathogens were recovered. The only organisms present were of the commensal group. All these strains were shown by test to have no proteolytic activity. This is bacteriologic proof that the gross surgical pathologic condition of a soft-parts wound gives more information than the routine bacteriologic study of that wound. Many thousands of similar soft-parts wounds have been closed or grafted on this basis.^{7, 21} It

appears that 5 to 10 per cent of these wounds subsequently show some local inflammatory reaction but there has been no reported instance of serious infection.

Case 31 typifies a *dirty* soft-parts wound with no evidence of invasive infection. Anaerobic infection of residual dead tissue was recognized. Clinically, it was impossible to tell whether this was infection with wound pathogens or with potentially invasive *Clostridia* acting as wound pathogens. Sec-

TABLE XVI
INFECTED WAR WOUND OF THE THIGH

Age of No. Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
			True Pathogens	Wound Pathogens	Commensals
13. 26 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Nonhem. Strept.</i> (anaer.)	<i>Nonhem. Strept.</i> (anaer.) <i>Micrococcus</i> (micro-aer.)
14. 45 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. A)	<i>Cl. putrificus</i> group	<i>Micrococcus</i> (micro-aer.) Diphtheroid
15. 45 days	C. F.	Wound suppuration	<i>Cl. perfringens</i>	<i>Cl. putrificus</i> group	<i>Staph. albus</i> Enteric <i>Strept.</i> <i>Micrococcus</i> (micro-aer.)
16. 5 days	C. F.	<i>Clostridial</i> myositis	<i>Cl. perfringens</i>	<i>Cl. sporogenes</i> <i>Pseudomonas</i>	<i>Escherichia</i> <i>Micrococcus</i> (anaer.) 2 <i>Micrococcus</i> (micro-aer.) Enteric <i>Strept.</i>
17. 7 days	C. F.	Wound suppuration	<i>Cl. perfringens</i> <i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Clostridium</i> (unident.)	<i>Clostridium</i> (unident.) <i>Micrococcus</i> (anaer.)
			<i>Hem. Strept.</i> (gr. A)	<i>Paraaerobacter</i>	<i>Nonhem. Strept.</i> (micro-aer.)
18. 41 days	C. F.	Wound suppuration	<i>Hem. Strept.</i> (gr. ?)	<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group	<i>Clostridium</i> (unident.) <i>Escherichia</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (micro-aer.) <i>Micrococcus</i> (anaer.)
19. 17 days	C. F.	Wound suppuration	<i>Cl. novyi</i>	<i>Cl. sporogenes</i> <i>Actinomyces</i>	<i>Cl. tertium</i> <i>Aerobacter</i> Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.) Diphtheroid
20. 27 days	C. F.	Wound suppuration	<i>Staph. aureus</i>	<i>Cl. sporogenes</i> <i>Cl. capitovialis</i> (?) <i>Actinomyces</i>	Gram-neg. bacillus (unident.) <i>Staph. albus</i> <i>Paraescherichia</i> <i>Nonhem. Strept.</i> Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (anaer.) 2 <i>Micrococcus</i> 2 <i>Micrococcus</i> (anaer.) 2

ondary wound excision was performed, penicillin was given and the wound closed by secondary suture five days later. Cultures of the wound demonstrated only proteolytic anaerobes and commensal bacteria.

Cases 32, 33 and 34 were *clean* wounds in association with compound comminuted fractures. Complete débridement of a fracture cannot be performed without needless sacrifice of bone. Nor does devitalized bone in a wound convey the same hazard of life endangering infection as devitalized muscle. Clinical experience has recognized the constant contamination of a compound fracture site after a lapse of more than six hours. Cultural studies of the

blood clot from the fracture site in these otherwise clean wounds revealed toxigenic and proteolytic *Clostridium* types. Clinical appraisal must take this probable contamination of the compound fracture into consideration. Penicillin has been recommended at the time of débridement for all compound fractures. It is considered mandatory for all secondary operations upon wounds complicated by fracture. Secondary closure of wounds over compound fractures is *not necessarily skin closure*. The technical objectives are obliteration of dead space and the covering of exposed cortical bone with vascular soft parts. Simple skin wounds will usually epithelize long before the fracture has healed. Bone defects or severe comminution contradict complete closure of all wounds. Dependent drainage of the fracture site must be established in anticipation of the ultimate septic decomposition of a contaminated hematoma.

Cases 35 and 36 are instances of dry gangrene after arterial injury. The cultures were biopsies of dead muscles taken at a considerable distance from the site of compound injury. Actively proteolytic bacteria were recovered in both cultures. The association of dead tissue and proteolytic bacteria is so constant as to suggest it as an inevitable consequence of incomplete débridement.

The bacteriologic picture and the clinical problem presented by the clean soft-parts wound must be distinguished from that common to the suppurative soft-parts wound and the wound complicated by fracture. Potentially invasive or toxigenic anaerobes have been demonstrated in both these latter types of wounds. The absence of clinical signs of invasiveness or toxemia cannot exclude the presence of true pathogens existing in the wound in their alternative rôle as proteolytic bacteria. Two cases of fatal gas gangrene are known to have followed secondary operations upon compound fractures without protective penicillin therapy. The superiority of penicillin over sulfonamide for these infections has been generally acknowledged.^{22, 23} No fatalities have been recorded from infection as a consequence of secondary operations, including internal fixation, for several hundred compound fractures receiving penicillin. The soft-parts wounds with deep recesses, suppurative soft-parts wounds and compound fractures merit penicillin therapy as an adjunct to primary and secondary surgical management on the basis of an established risk of toxigenic *Clostridium* infection. The important technical considerations in the reparative management of compound fractures have been reviewed by Hampton.²⁴

The major risk of invasive infection in the cleanly excised soft-parts wound is from the *beta hemolytic Streptococcus*. It is impossible to assess the therapeutic value of routine sulfonamide therapy after initial surgery in this group of cases. Of greatest importance to this program of secondary suture without further chemotherapy is the absence of any delay between removal of the first dressing and closure of the wound. The gross surgical pathologic picture of the soft-parts wound is a reliable index of infection only after the lapse of three to five days from the time of the last dressing. Chemo-

TABLE XVII

SEPTIC ARTHRITIS AS A COMPLICATION OF WAR WOUNDS

Age of No. Wound	Injury	Clinical Diagnosis of Infection	Bacteria Isolated from War Wounds		
			True Pathogens	Wound Pathogens	Commensals
21. 20 days	Wrist	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Aerobacter</i> Enteric <i>Strept.</i>
22. 20 days	Elbow	Septic arthritis		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Proteus mirabilis</i>	Enteric <i>Strept.</i>
23. 25 days	Knee	Septic arthritis	<i>Cl. tumefaciens</i> (?)	<i>Cl. sporogenes</i> <i>Paraaerobacter</i>	Enteric <i>Strept.</i> Diphtheroid
24. 23 days	Knee	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	<i>Micrococcus</i> (micro-aer.) Gram-neg. bacillus (unident.)
25. 27 days	Knee	Septic arthritis	<i>Staph. aureus</i>	<i>Cl. sporogenes</i>	Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.)
26. 24 days	Knee	Septic arthritis		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group <i>Pseudomonas</i>	Enteric <i>Strept.</i> <i>Clostridium</i> (unident.) <i>Micrococcus</i> (anaer.)

TABLE XVIII

BACTERIOLOGY OF WAR WOUNDS WITHOUT GROSS INFECTION—ALL WOUNDS HEALED WITHOUT INFECTION UNDER TREATMENT AS INDICATED

Age of No. Wound	Injury and Appearance	Bacteria Recovered from Wound			Treatment	Chemo- therapy
		True Pathogens	Wound Pathogens	Commensal		
27. 6 days	S. P., clean			Enteric <i>Strept.</i> <i>Bacillus</i>	Skin graft	0
28. 6 days	S. P., clean			Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.)	Sec. closure	0
29. 3 days	S. P., clean			<i>Nonhem. Strept. 2</i> <i>Staph.</i> (non-pig.)	Sec. closure	0
30. 3 days	S. P., clean			<i>Cl. tertium</i> Enteric <i>Strept.</i> <i>Micrococcus</i> (anaer.)	Sec. closure	0
31. 7 days	S. P., dirty		<i>Cl. sporogenes</i> <i>Cl. putrificus</i> group	Enteric <i>Strept.</i> <i>Nonhem. Strept.</i> (anaer.) <i>Micrococcus</i> (anaer.) <i>Micrococcus</i> (micro-aer.)	Excision and Sec. closure	Pen.
32. 2 days	C. F., clean	<i>Cl. septicum</i>	<i>Cl. sporogenes</i> <i>Micrococcus</i> (anaer.)	Enteric <i>Strept.</i> <i>Bacillus</i> <i>Bacterium</i>	Sec. closure	Pen.
33. 7 days	C. F., clean	<i>Cl. per- fringens</i> <i>Cl. septicum</i>	<i>Cl. sporogenes</i>	Enteric <i>Strept.</i> <i>alpha hem. Strept.</i> <i>Staph. albus</i> <i>Bacterium</i>	Int. fixation, and sec. closure	Pen.
34. 10 days	C. F., clean	<i>Cl. per- fringens</i>	<i>Cl. sporogenes</i> <i>Clostridium</i> (unident.) <i>Pseudomonas</i> <i>Paraaerobacter</i> <i>Cl. sporogenes</i>	<i>Cl. tertium</i> <i>Nonhem. Strept. 2</i> Gram-negative bacillus (unident.) <i>Nonhem. Strept.</i> <i>Aerobacter</i>	Sec. closure	Pen.
35. 12 days	Dry gangrene (muscle culture)				Amputation	0
36. 6 days	Dry gangrene (muscle culture)		<i>Pr. vulgaris</i>	<i>Staph.</i> (nonpig.)	Amputation	0

CHEMOTHERAPY IN WOUND MANAGEMENT

therapy should complement secondary suture of the wound contaminated by a recent dressing.

Local penicillin therapy was used occasionally, but only as a supplement to systemic administration in the treatment of injuries or infections involving the joints, serous cavities or subarachnoid space since with systemic administration it does not readily penetrate these cavities. No local therapy was used in other wounds, reliance being placed on systemic penicillin to check or abolish invasive infection. The fundamental surgical philosophy of reparative wound management assigns priority to the technical surgical care of the wound.

In the years before there was a plentiful supply of penicillin, Florey and Cairns⁵ were privileged to make an extensive investigation of local penicillin therapy. It is interesting that the local use of chemotherapy necessitated the

TABLE XIX

CLINICAL IMPLICATIONS OF A SURGICAL PHILOSOPHY ACCEPTING OR REJECTING LOCAL APPLICATION OF A CHEMOTHERAPEUTIC AGENT

Local Chemotherapy	Systemic Chemotherapy
1. Assigns priority to sterilization of wound	1. Assigns priority to surgical preparation of the wound
2. Assumes a wound can be sterilized of all pathogens	2. Asserts that no available antibacterial agent removes all pathogens from a wound
3. Regards "gram-negative pus" as an acceptable component of wound healing	3. Regards "gram-negative pus" as evidence of locally necrotizing infection with aerobic wound pathogens
4. Endorses "wound trimming" as a substitute for complete débridement	4. Permits no compromise with substitutes for the complete excision of devitalized tissue
5. Clinical management is dictated by bacteriologic findings	5. Clinical management is dictated by gross pathology of wound
6. Recommends repeated dressings or irrigations of the wound	6. Demands an undisturbed and occlusive pressure dressing and splinting
7. Recognizes clinical failures as "drug failures"	7. Recognizes clinical failures as errors in surgical judgment or technic.

evolution of a philosophy of wound management differing in several important details from the philosophy of reparative wound management (Table XIX). It was the considered opinion of the British investigators that "if large quantities of penicillin were freely available, there can be no question that parenteral administration should in nearly all cases be practiced."

DISCUSSION.—The initial surgical management of a war wound is the most important single factor in determining ultimate salvage of the battle casualty. Dead or devitalized tissue must be excised without surgical insult and the war wound must be left open.^{25, 26} Absence of fixed forward hospitals in World War II made it impractical to attempt primary suture as practiced by Le Maitre²⁷ and Pool²⁸ within the forward area in World War I.

There are no simple rules for subsequent management of the open wound after débridement. The problem is frequently complicated by the presence of residual dead tissue and blood clot, especially in compound fractures. In earlier surgical experience the hazard of invasive infection dictated primary consideration of the identity of the bacteria in war wounds. The bacteriologic

picture was confused by the wide variety of organisms concerned in the septic decomposition of dead tissue protein. An altered perspective followed the introduction of antibacterial agents for the control of invasive infection. The major problem in wound management became the control of local suppuration.

It is believed the bacteriologic and clinical evidence presented in this report again establishes the nutritional pabulum of dead tissue and wound exudate protein as more important than the identity of the bacteria concerned with its liquefaction. Dead tissue protein and hematoma sustain anaerobic and aerobic bacteria. Wound exudate protein is most available to aerobic bacteria. The gross surgical pathologic condition of the open wound is more directly and accurately informative than any reasonable bacteriologic analysis. It is pertinent to review older methods of wound management from this vantage point.

The Carrel-Dakin's regimen provided for the *chemical digestion of residual dead tissue protein*.²⁹ It failed to provide protection against invasive hemolytic streptococcal infection. This risk was increased by the necessity for frequent dressings. An elaborate dressing routine was designed to prevent contamination from the noses and throats of the surgical attendants. The presence of *hemolytic Streptococci* in the wounds became the chief clinical concern of the surgeon. Bacteriologists were given a full-time task in the counting and culturing of streptococci in wound exudates. In spite of all these precautions it was demonstrated in World War I that streptococcal contamination was present in many of the wounds during the period of hospitalization.³⁰ Under these circumstances secondary surgical procedures proved hazardous.²⁸ The method was so painful, elaborate and time-consuming that it was gradually abandoned as routine treatment for open wounds following compound injuries in civilian life.

The closed plaster methods of Pirogoff, Orr and Trueta provided for the *bacterial digestion of dead tissue protein*. Invasive bacterial infection was reduced to a minimum by infrequent changes of dressings and prolonged splinting. The locally necrotizing action of retained products of suppuration was minimized by dependent drainage and the use of plaster to absorb wound exudates. This method accepts the ultimate sequestration of incompletely detached and exposed bone fragments and permits no direct attempts to revascularize such fragments. The prolonged suppuration makes some degree of wound cachexia inevitable. The resultant weight loss and muscular atrophy make it difficult and often impossible to maintain bone alignment with infrequent plaster changes in many instances. The closed plaster method pays a price in fracture deformity and the proteolytic digestion of collagenous tissue structures. It is still the method of choice in the management of overwhelming numbers of casualties. It retains a clinical usefulness for the management of incompletely sequestered bone fragments provided vulnerable soft-parts are protected from the wound exudate by a surface of granulation tissue or epithelium. Its relative advantage in the control of invasive infection has been superseded by available antibacterial agents.

The reparative method of wound management provides for the *surgical*

*excision of dead tissue protein and a closed wound.*²⁶ It also permits an attempt to revascularize partly detached bone fragments by apposition of soft-parts over exposed bone. Invasive infection is controlled by the *systemic* use of chemotherapeutic agents. Anaerobic wound infection is controlled by the excision of dead tissue protein and the avoidance of primary wound closure. Aerobic wound infection is controlled by preventing wound exudation through the use of splints, pressure dressings and secondary closure of clean wounds. Contamination of wounds with air-borne wound pathogens is decreased by the abandonment of needless changes of dressing. Repeated local applications of antibacterial agents are incompatible with the efforts to prevent wound exudation and the accumulation of exudate protein in the wound. The reparative program of wound management extends the scope of surgery to the more effective correction of deformity, lessens the hazard of invasive and chronic sepsis and accelerates rehabilitation of the patient.⁷

The rôle of chemotherapy in wound management in the Mediterranean Theater was as an adjuvant to a surgical program of reparative wound management. No antibacterial agent was used for the prophylaxis of infection. The drugs were used therapeutically to control impending or established invasive infection. Wound suppuration was not controlled by chemotherapy alone. The topical use of antibacterial agents was contradicted by the philosophy of reparative wound management.

Lest it escape the casual reader, these investigations have affirmed the soundness of the listerian principle of treating the local wound by surgical measures. The recent advances in wound management, if they be so adjudged, are attributable to the improved protection of the individual from the systemic consequence of local wounding.

CONCLUSIONS

1. *Lister's Axiom*: "The essential cause of suppuration in wounds is decomposition brought about by the influence of the atmosphere upon blood or serum retained within them, and in the case of contused wounds, upon portions of tissue destroyed by the violence of the injury."

Corollary: The presence of a pabulum of wound protein nutritionally acceptable to wound pathogens is of far greater clinical importance than the identity of the bacterial contaminants concerned with its septic decomposition.

2. *Lister's Axiom*: "The pernicious influence of decomposing animal matter upon the tissues has probably been underrated. . . . Before a raw surface has been granulated, an acrid discharge acts with unrestrained effect upon it . . . producing by its caustic action a greater or less extent of slough."

Corollary: Wound suppuration is an intolerable complication of sound management, especially in the recent wound.

3. *Lister's Axiom*: "Putrescent serum would produce inflammatory disturbance."

Corollary: The control of wound exudation is as important as the excision of devitalized tissue in the prevention of wound suppuration.

4. *Lister's Axiom*: "Supposing an antiseptic . . . to be employed, . . . the wound would be more or less irritated by it, and in proportion to this irritation would effusion be increased . . . ; and if, in spite of the antiseptic means, active septic matter had been introduced, putrefaction . . . would be the natural result."

Corollary: "Experience in wound management justifies the abandonment of local use of any chemical agent in a wound for its supposed antiseptic effect in the prevention or treatment of infection." War Department Circular Letter No. 160, par. V, 1, dated June 1, 1945.

5. *Lister's Axiom*: "The suppression of the septic element enlarges the capabilities of surgery in the constitutional direction no less than in the local."

Corollary: Specific chemotherapy, given by the systemic route, is a proper adjuvant to an expanded surgical program for more effective wound management.

BIBLIOGRAPHY

- ¹ Lyons, C.: Penicillin Therapy of Surgical Infections in the U. S. Army: A Report. J. A. M. A., **123**, 1007, December 18, 1943.
- ² Meleney, Frank L., et al.: The Study of the Prevention of Infection in Contaminated Accidental Wounds, Compound Fractures and Burns. ANNALS OF SURGERY, **118**, 171, August, 1943.
- ³ Lyons, C., Queen, F. B., Hollenberg, H., Sweeney, J. S., and Ingram, A. J.: Penicillin Therapy for Septic Compound Fractures in a Military Hospital: Interim Report, under Contract OEMcmr 275, May 21, 1943, to Committee on Medical Research of the Office of Scientific Research and Development.
- ⁴ Churchill, E. D.: A Classification of Wound Infection. Unpublished, but quoted by Whipple, A. O.; S. G. and O., **80**, 263, March, 1945.
- ⁵ Florey, H. W., and Cairns, H.: Investigation of War Wounds—Penicillin: A Preliminary Report to the War Office and the Medical Research Council on Investigations Concerning the Use of Penicillin in War Wounds. War Office (A. M. D. 7), October, 1943.
- ⁶ Carpenter, G. K., and Rosenfeld, R. T.: Certain Reparative Problems in Orthopedic Surgery. S. Clin. North America, **24**, 420, April, 1944.
- ⁷ Churchill, E. D.: Surgical Management of Wounded in Mediterranean Theater at Time of Fall of Rome. ANNALS OF SURGERY, **120**, 268, September, 1944; *idem*: Tr. Am. S. A., **62**, 268-283, 1944.
- ⁸ Ferrer, J. M., Jr.: Rôle of Penicillin in the Management of Infection. J. Bone & Joint Surg., **26**, 522, July, 1944.
- ⁹ Hall, Ivan C.: The Occurrence and Possible Significance of Bacillus Tetani in Compound Fractures, Lacerations, Gunshot Wounds and Burns. Surgery, **18**, 377, September, 1945.
- ¹⁰ Lyons, C., and Rustigian, R.: Chemotherapy and the Reparative Management of Battle Wounds, Essential Technical Medical Data, Mediterranean Theater of Operations, October, 1944.
- ¹¹ Rustigian, R., Lyons, C., and Cipriani, A.: Bacteriologic Investigation of War Wounds: Report to the Office of the Surgeon, Mediterranean Theater of Operations, August, 1945 (to be published).
- ¹² Harvey, S. C.: Treatment of Infection with Particular Reference to Peritoneum. New York State J. Med., **44**, 1883, September 1, 1944.
- ¹³ Lockwood, J. S.: Definition of Objectives and the Importance of Controls in Evaluating the Local Use of Sulfonamides in Wounds. Surg., Gynec. & Obst., **79**, 1, July, 1944.

- 13 MacLennan, J. D.: Anaerobic Infections of War Wounds in the Middle East. *Lancet*, **2**, 63, 94, 123, 1943.
- 15 Prevot, A. R.: *Manual de classification et de determination des bacteries anaerobies*. Monograph de L'Institute Pasteur, 1940, Masson et Cie., Paris.
- 16 Stuart, C. A., Wheeler, K. M., Rustigian, Robert, and Zimmerman, C. A.: Biochemical and Antigenic Relationships among Paracolon Bacteria. *J. Bacter.*, **45**, 101, February, 1943.
- 17 (a) Christensen, L. R.: Streptococcal Fibrinolysis: A Proteolytic Reaction due to a Serum Enzyme Activated by Streptococcal Fibrinolysin. *J. Gen. Physiol.*, **28**, 363, 1945.
(b) Christensen, L. R., and MacLeod, C. W.: A Proteolytic Enzyme of Serum: Characterization, Activation and Reaction with Inhibitors. *J. Gen. Physiol.*, **28**, 559, 1945.
- 18 Lister, Joseph: On a New Method of Treating Compound Fracture, Abscess, etc.: With Observations on the Conditions of Suppuration. *Lancet*, **1**, 326, 357, 387, 507 and **2**; 95, 1867.
- 19 Lister, Joseph: An Address on the Relation of Micro-organisms to Inflammation. *Lancet*, **2**, 695, 1881.
- 20 Lister, Joseph: An Address on the Treatment of Wounds. *Lancet*, **2**, 863 and 901, 1881.
- 21 Wilson, H., and Threadgill, F. D.: Secondary Suture of War Wounds. *Bull. U. S. Army M. Dept.*, **82**, 77, November, 1944.
- 22 Notes on Care of Battle Casualties. *War Dept. Tech. Bull. Med.*, 147, March, 1945.
- 23 Therapeutic Use of Sulfonamide Compounds. *War Dept. Tech. Bull. Med.*, 172, June, 1945.
- 24 Hampton, Oscar P., Jr.: Reparative Surgery of Compound Battle Fractures in the Mediterranean Theater of Operations. *ANNALS OF SURGERY*, **122**, 289, September, 1945.
- 25 DeBakey, M. E., and Carter, B. N.: Current Considerations of War Surgery. *ANNALS OF SURGERY*, **121**, 545, May, 1945.
- 26 Lyons, C.: The Philosophy of Wound Management in the United States Army. *Bull. Am. Coll. Surgeons*, **30**, 13, February, 1945.
- 27 LeMaitre, Rene: Suture of War Wounds. *War Med.*, **2**, 790, December, 1918.
- 28 Pool, E. H.: War Wounds: Primary and Secondary Suture. *J. A. M. A.*, **73**, 383, August 9, 1919.
- 29 Fiessinger, Noel, and Clogue, Rene: Biological Study in the Action of Alkali and Hypochlorite Solution in the Treatment of War Wounds. *Rev. de Chirurg.*, September-October, 1917, and abstracted in *War Medicine*, **2**, 361, 1918-1919.
- 30 Beebe, Theodore C.: Wound Bacteriology at Evacuation Hospital No. 1, American E. F., France. *War Med.*, **2**, 1023, January, 1919.

DISCUSSION.—DR. J. ALBERT KEY, St. Louis, Mo.: I have not understood why the Army threw the local sulfonamides out the window before they had anything adequate to put in their place. I concede that penicillin is a more potent agent than the sulfonamides, and admit that neither will sterilize a wound full of dead tissue or foreign bodies. But there is not the slightest doubt in my mind that pathogenic bacteria do not grow as well in a medium saturated with sulfanilamide or sulfathiazole, or which contains an adequate concentration of penicillin, as in the same medium in which those agents are absent.

We know there are limitations to the use of local chemotherapy. It must be combined with competent surgery, as competent as you can get. If I had a compound wound and was not going to get to a surgeon for 12 hours, I would like to have somebody throw a handful of sulfanilamide in that wound and put a dry pressure dressing on it. I have not seen military surgery at the front in this war, but I have seen civilian wounds, and the results are good when treated with local and general chemotherapy. A lot of benefit has been due to chemotherapy and some to more radical surgery. I believe that with adequate local and systemic chemotherapy radical excision can be modified. If

you tell the average surgeon he has to do complete excision of every wound he will do a block excision and may do more harm than good. We must save as much tissue as possible.

I still use local sulfonamides but I have stopped using powder. I wash the wound out with a saturated solution of sulfanilamide or sulfathiazole, or of both, and I have never had such nice healing of wounds. When I review my clinical experience with local chemotherapy during the past six years, all the bacteriologic evidence that could be piled on this table would not make me change my mind. But it must be used intelligently.

DR. ROY D. McCCLURE, Detroit, Mich.: I was on the subcommittee of Infected Wounds and Burns of the National Research Council, and I remember Doctor Key's criticism of that Committee and Meleney's report to the American Surgical Association. I know of no member of the Committee who has changed his mind as to the conclusion reached that the use of the sulfa drugs in wounds is far from the ideal treatment. This conclusion was reached after careful study of results reported by a sufficient number of clinic projects with a large number of cases so treated and similar numbers of control cases where the sulfa drugs were not used locally.

Those of us who were in the last war realize what an advance has been made in this war in the opportunities for research in the Army itself. Doctor Lyons was on the Subcommittee of the National Research Council. When he was taken into the Army and assigned to Halloran Hospital there was opportunity in the splendid laboratory for research studies on penicillin, and this work was beautifully executed. Our eyes were opened to the opportunity that should always be present in the Army and Navy for the adequate study of new drugs and technics. We congratulate Surgeon General Kirk for making this possible. It was not possible in the last war, to the best of my knowledge.

COL. GEORGE G. FINNEY, Baltimore, Maryland: I do not want to further this argument, but I do want to put forward some facts I had a chance to observe during the Okinawa campaign. Before going into this campaign, it was felt that the incidence of *Clostridium* infections might be considerably increased. The reason for this was the extensive use of night soil for fertilizer as the war moved east and, therefore, the incidence of gas gangrene might be greater than it had been up to that time. The facts were, so far as we can tell from examining the records of nearly 20,000 battle casualties taken care of in Field Hospitals during that campaign, that there were only 48 definite clinical *Clostridium* infections. I emphasize clinical because I think this is the only proper way to make a diagnosis since the organism can often be grown from wounds where there is no clinical evidence of gas gangrene. I am not even sure that all 48 were true *Clostridium* infections.

Because of the volume of cases and, for a considerable part of the campaign, an inadequate number of surgeons, all the wounded did not receive surgery as early as we would have liked. In fact, some of the less serious cases went as long as two or three days before adequate débridement was done. The one type of therapy all battle casualties received immediately was systemic penicillin. We did not use, except sporadically, local chemotherapy in wounds. I am simply offering this for what it is worth, but it does make one wonder whether or not systemic penicillin did not have some definite beneficial effect. It must be emphasized, however, that there is no substitute for proper surgery.

DR. CHAMP LYONS, New Orleans, La. (closing): I would like to emphasize just one statement. Doctor Key brought out that he thought through the use of local chemotherapy it was possible to compromise with excision of devitalized tissue. I think the total military experience condemns any attempt at wound treatment short of removal of all devitalized tissue.

THE PREVENTION AND TREATMENT OF POSTOPERATIVE LYMPHEDEMA OF THE ARM*

DONALD GUTHRIE, M.D., AND GERARD GAGNON, M.D.

SAYRE, PA.

POSTOPERATIVE LYMPHEDEMA of the arm has occurred ever since Halsted and Willy Meyer advocated the radical mastectomy—removing the pectoral muscles and the axillary contents. Fortunately, this distressing condition is not common but it is surprising that so little thought has been given to its prevention and treatment. In fact, it has been possible to find but 13 published articles in the British and American literature dealing specifically with this subject.

While it is not within the scope of this paper to discuss any other aspects than the prevention and treatment of postoperative swelling of the upper limb, in the absence of demonstrable recurrence, it would seem appropriate to summarize briefly some of the current trends concerning the cause of such swelling.

Halsted was the first to call the attention of the medical profession to this puzzling condition. His classic article, published in 1921, has shed a great deal of light on the subject. He was of the opinion "that although blocking of the lymphatics and occasionally also of the veins was the underlying factor, infection played a conspicuous part in the determination of the amount of swelling and the time of its manifestation." The infection, he said, "may be so mild in degree as to escape observation even of those constantly on the lookout for it." Reichert and Bidgood provided experimental support of Halsted's theory. They showed that, after complete division and suture of all the tissues of the hind legs of dogs, except the femur, the femoral vessels and nerve trunks, lymphedema failed to occur and new lymphatics could be shown to cross the line of suture by the fourth day and that, by the eighth day "the regeneration was physiologically adequate." That the Reichert and Bidgood experiment and radical mastectomy are two comparable procedures is very hard to sustain. A clean circular cut across the limb was made and resutured, while in radical mastectomy, as it has been pointed out by Devenish and Jessop, not only is the whole mass of regional lymph nodes removed but also varying lengths of the main lymphatics of the arm.

Veal, believing that the obstruction on the axillary vein is a more important factor in the production of lymphedema than Halsted had shown, classified lymphedema into: lymphatic obstruction; axillary vein occlusion or constriction; and combined lymphatic and venous obstruction. Some of Veal's main statements concerning the nature and pathogenesis of the condition have been strongly challenged by Devenish and Jessop. In the most enlightening articles since Halsted's contribution, they have clarified much of the uncertainty that formerly existed about this subject.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

According to these writers "lymphatic obstruction alone is sufficient to cause the postoperative nonmalignant swelling, and the rise of venous pressure, as occurs during exercise (Hooker, 1911), can be a contributing factor in edema formation only in the presence of lymphatic obstruction. To explain the fact that not all the patients, subjected to a nearly identical operation, develop swelling of the arm they suggest the following theory: "The lymphatics in the subcutaneous tissues are chiefly large draining trunks with very few of the smaller vessels and very few capillary lymphatics. They do not lie directly on, and rarely in, the deep fascia (Gray, 1930). The infrequent development of the swelling following a standardized operation may be due to variations in

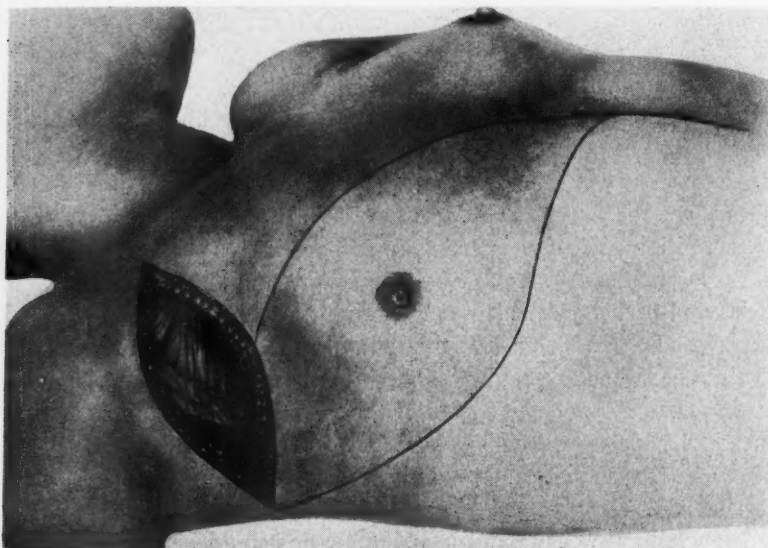


FIG. 1.—The Rodman incision.

the extent to which the main lymphatic trunks draining the upper limb are excised. When too many of the main lymphatics have been removed over too large an area, their regeneration may be inadequate to restore the lymph flow. The delay in onset of the swelling would be due to a combination of partial lymphatic obstruction and loss of skin elasticity."

In a review of 103 radical mastectomies performed on 100 patients, Holman, and his associates, found that the postoperative marked swelling was in direct relation to the incidence of infection which, in their series, was by far the greatest factor. Of 41 patients whose records showed infection, 38 developed swelling, and all 11 patients, in whom marked swelling was noticed, had either early or late infection, or both.

PREVENTION

Veal said: "It is easier to prevent postoperative edema after radical mastectomy than to cure it when it has occurred." If the surgeons were willing to focus as much attention upon the preventive measures of this complication as

POSTOPERATIVE LYMPHEDEMA OF ARM

upon the curative measures of the cancer, a tremendous progress might be registered. It must be clearly stated that the preventive measures, adopted to diminish the liability to postoperative edema, should not jeopardize the curative measures of cancer which constitute, as we have said before, our first consideration in surgery.

In our experience, swelling of the arm following radical mastectomy has been a very uncommon complication. The preventive measures thought to be effective at the Guthrie Clinic are the following: Placing the incision off the arm; a sharp anatomic dissection of the axillary contents; the use of very fine nonabsorbable sutures (we prefer size No. 80 cotton); no drainage; pressure dressing; early mobilization of the arm; and avoidance of infection.

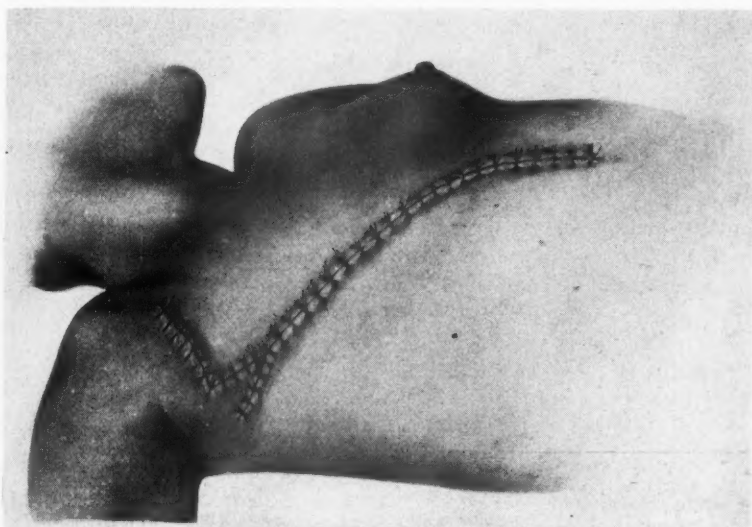


FIG. 2.—Closure without drainage.

We believe that it is very important to keep the incision off the arm; by extending the scar on the arm, there is danger of narrowing the axillary space and interfering with the mobility of the arm; the Rodman incision has been used in our cases with gratifying results (Fig. 1). It affords good exposure and has many other excellent features. At times, the case is found to be inoperable when the axilla is inspected, because such extensive metastases are found. This is best discovered at the beginning of the operation rather than after the breast has been completely mobilized, as is done in any operation which attacks the breast first and the axilla last. In 30 of 680 cases we reported in 1938, the operation was discontinued when the true condition in the axilla was discovered. In controlling some of the arterial blood supply to the breast and the muscles at its source, there is much less bleeding and the breast is handled less in this method, and there is less danger of expressing cancer cells into the circulation.

It is beyond question that trauma is deleterious to the healing of tissues,

particularly fatty tissues, and favors fibrosis and infection. It is suggested that sharp, gentle anatomic dissection should be used throughout the operation. Indeed, the axillary dissection should be carried out with the utmost care.

"While excision of all the lymphatics running from the breast to the axilla is essential, it might be possible deliberately to preserve some of the main lymphatic channels at the upper end of the arm. As pointed out by Gray, Dev-enish and Jessop these main lymphatic channels run in the fatty subcutaneous tissue. "These are, therefore, more likely to be preserved if the subcutaneous

tissue is left in the flaps and their reflection carried by dissection in a plane immediately superficial to the deep fascia on the upper flap from the axilla to a point midway along the clavicle."

Fine and preferably nonabsorbable suture material should be used. We believe that cotton meets all the requirements and is superior to all other types of suture material. It seems unnecessary to stress that the hemostasis should be meticulous and complete.

Drainage is not only useless but is harmful especially if the drain is allowed to lie against the axillary vessels. To put a drain in a mastectomy wound is to provide a beachhead to infection (Fig. 2). Should a serum pocket develop under the flaps, the chances of contamination, by aspirating the serum with a medium-sized



FIG. 3.—Early mobilization of arm.

needle, are less than by inserting a drain at the time of operation to prevent such a collection under the flaps.

The most important factor is undoubtedly the avoidance of infection which plays a definite rôle in occurrence of lymphedema. The factors we have mentioned above, plus absolute asepsis, we believe protect the patient against infection.

Prolonged immobilization of the arm following the operation should be condemned. Absolute free and early mobilization should be instituted. It is as important to mobilize the arm following radical mastectomy to prevent edema as it is to exercise the legs for prevention of phlebothrombosis and thrombophlebitis following operation in the pelvis. The proper application of this measure naturally involves coöperative understanding and action between the surgeon, the patient and the nursing staff. The patient is requested to move her arm as soon as she reacts from the anesthesia. She increases the range of motion until she can duplicate the Statue of Liberty position and until she is able to comb her hair and touch her thoracic spine (Fig. 3).

If roentgenotherapy is indicated, one should avoid a destructive type of dermatitis. While definite clinical experience is lacking, roentgenotherapy may precipitate chronic edema by blocking the lymphatics before collateral circulation takes place by favoring the formation of fibrosis.

Radical mastectomy should not be performed in the presence of infection, no matter how trivial, in the corresponding upper limb. Furthermore, the patient, before leaving the hospital, should be instructed about the importance of avoiding injury and infection of hands and fingers and, should infection, even minor, develop, she should seek immediate medical attention.

We have examined the last 100 living patients subjected to radical mastectomy prior to 1945. Fifty-six of them had axillary metastasis at the time of operation. Postoperative roentgenotherapy was administered to all those with axillary metastases. In 71 patients the wound healed *per primam*, and in 29 it healed by second intention. In six patients the presence of infection was manifest. All these patients were operated upon without primary or secondary skin grafting. Skin grafting, *per se*, does not seem to be a factor in reducing the incidence of lymphedema. Eight patients developed swelling of the arm following operation; in six, the edema has already subsided with conservative measures. Two patients have definite and marked chronic lymphedema; one patient has been operated upon, and her case is included in the list of patients reported in this paper. The other patient has been advised to be operated upon but as yet has not given her consent.

TREATMENT

For lymphedema due to a recurrence of the malignancy nothing can be offered other than symptomatic treatment. This paper discusses the treatment of lymphedema where recurrence can absolutely be ruled out as an underlying factor in its production. Here, we no longer can be satisfied with palliative measures.

The few writers who have studied the subject of postoperative lymphedema have either expressed the opinion that no treatment has been devised yet for its relief or have advocated conservative measures such as massage, rest, elevation of the arm at night and the use of an elastic bandage—measures that are not of lasting benefit.

As far as operative procedures are concerned, the Kondoleon operation has proved to be of no value. Standard has obtained an excellent result in one case by excising an oval segment of skin and deep fascia, exposing the bare muscles on the mesial aspect of the arm. The skin of the chest wall opposite the segment was opened through the deep fascia to the muscles (*serratus magnus*) covering the thorax. The skin edges were sutured by interrupted silk sutures and the arm immobilized against the chest wall. While this operation furnished an adequate lymphatic flow, we think the mobility of the arm was greatly restricted. Guthrie and French, in 1942, published an exceptionally simple operative method of treatment, devised by W. C. Beck, of Chicago, for postoperative lymphedema.

It is the purpose of the authors to discuss before the Association, the Beck operation and to report their results in a small number of cases. The method is so safe and so easy to perform, they believe it is justifiable to employ it in all cases where the edema can be proven not to be due to metastases.

"A small incision is made on the arm, about 2 cm. long, which is deepened into the edematous tissue. Into this incision a large eight-inch forceps is introduced. The forceps is pushed subcutaneously as far as it will go, and a second small incision is then made over the tip of the forceps. The tip of the forceps

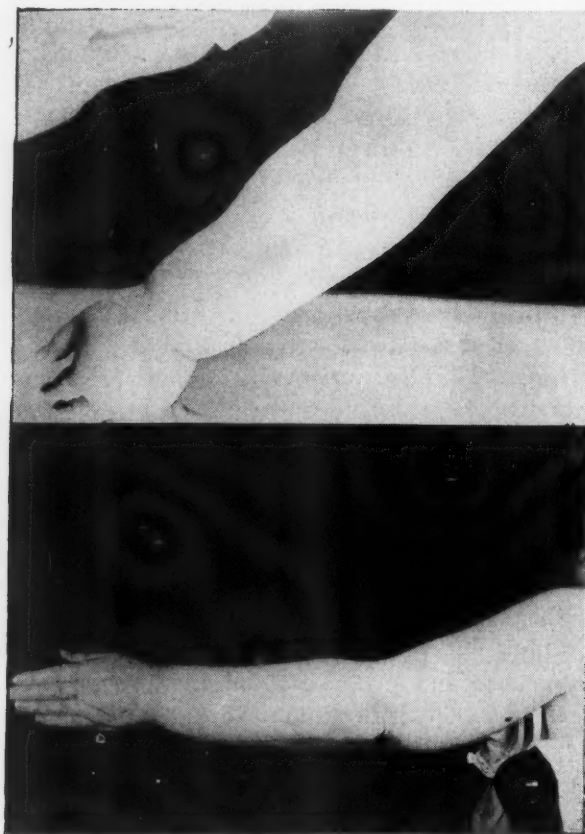


FIG. 4.—Case 1: Preoperative and postoperative.

now grasps a celloidin strip, 1 cm. wide by $1\frac{5}{16}$ cm. long, and pulls it through. The ends of the celloidin strip are then pushed beyond the incision so that the entire strip lies in the subcutaneous tissue. Usually two strips are used in front and three behind, pushed through the subcutaneous tissue from the arm to the chest. The small incisions are then closed with one or two sutures. The arm is placed on an aeroplane splint, and the strips remain in place for three weeks. At this time, the incision in the normal tissue is reopened and the strips removed. This can be done under local anesthesia."

POSTOPERATIVE LYMPHEDEMA OF ARM

CASE REPORTS

Case 1.—A 59-year-old white female, had had a radical mastectomy ten years previously, in this Clinic, for carcinoma of the left breast, with axillary metastases. Postoperative convalescence was uneventful except for necrosis of the central portion of the wound, which healed by granulation. Within a few months after operation she developed a brawny edema of the arm that increased markedly within the preceding one or two years before admission. Pulmonary symptoms of chest pain and cough had been present for several months and were becoming worse. Roentgenologic examination failed to show

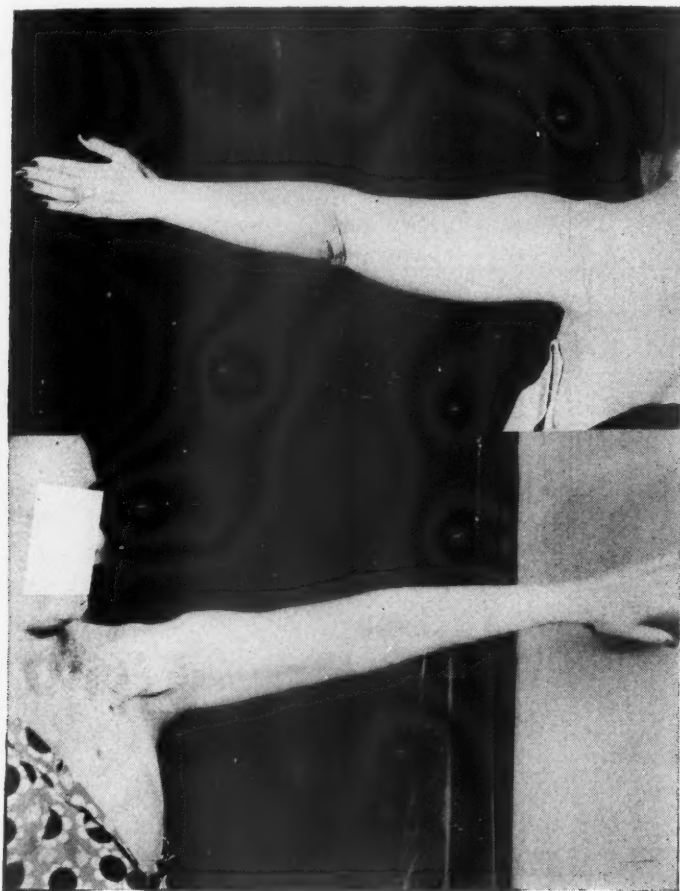


FIG. 5.—Case 2: Preoperative and postoperative.

evidence of metastasis to the lung, and no axillary or supraclavicular nodes were palpated. The arm was greatly enlarged and there was brawny edema from the shoulder to the finger tips, most marked in the forearm. The Beck operation was performed, and within a few days the extremity had shrunk markedly in size. This patient was followed for over three years and the arm remained practically normal in size. Her most recent examination disclosed a late metastatic lesion of the lung, but the arm remained perfect. She died a few months later (Fig. 4).

Case 2.—A 48-year-old, white female, who had had a radical mastectomy performed elsewhere, in 1938, for carcinoma of the breast, with axillary involvement. Roentgenotherapy was administered postoperatively, and within three months she developed an

edema of the arm—usual treatment was unsatisfactory. The edema remained fairly stationary for two years, and was mostly in the arm. Brawny edema was present, not associated with recurrent chills or fever, and with no pulmonary symptoms.

Roentgenologic examination failed to show evidence of metastasis to the lungs and no axillary nodes were palpable. The arm was greatly enlarged, and there was edema from the shoulder to the elbow. The skin of the axillary area was pigmented and a long scar on the chest, not extending out on the arm, was present. In May, 1941, an operation, after the method of Beck, was performed, and within a few days the extremity had shrunk markedly in size, by actual measurement. The arm was supported by an aeroplane splint and an elastic bandage was applied for a few days. The celloidin strips were removed after three weeks, and the patient was discharged in good condition. The result in this case was satisfactory for some time. A recent communication reports an axillary recurrence has taken place, the swelling has returned, and that the patient is receiving irradiation (Fig. 5).

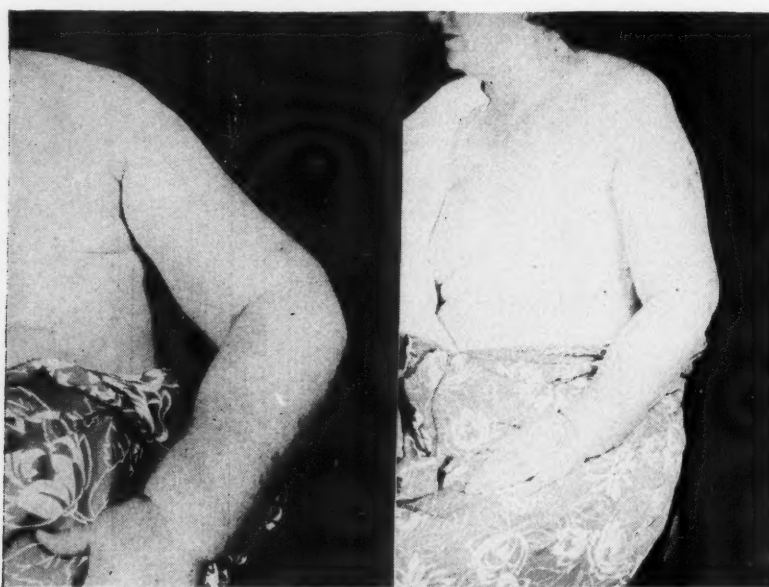


FIG. 6.—Case 3: Preoperative and postoperative.

Case 3.—A 61-year-old, white female, had had a radical mastectomy elsewhere 25 years before, for what was thought to be carcinoma of the breast. Within a few months her arm became markedly swollen, tense, painful, and produced considerable disability. Her chief complaints were recurrent attacks of severe chills, fever, pain, and increased swelling of the arm. At times, during this period, she had had cough, chest pain and digestive upsets, resembling biliary tract disease. The edema had been constant and there was no recent change in her physical condition. No roentgenotherapy had been administered to this patient, and a history of wound infection at the time of operation was obtained.

Roentgenologic examination failed to show evidence of metastasis to the lung, and no axillary nodes were palpable. The edema was extensive from the tip of the shoulder to the finger tips. The arm was very heavy and the patient requested that the arm be amputated if no relief could be promised her. Operation was performed in June, 1942, and five celloidin strips were placed subcutaneously from arm to chest. The arm was placed in an aeroplane splint and within a few days a remarkable reduction in size and texture of the skin had taken place. The strips were removed three weeks after operation. Three days

POSTOPERATIVE LYMPHEDEMA OF ARM

later she developed an obscure pulmonary complication characterized by fever, pain and chills, which were thought to be an acute pneumonic process. This was further complicated by a return of her old syndrome of gastro-intestinal upset and chills, without any pain, swelling or change in her arm. The exacerbation lasted exactly two weeks and she recovered as rapidly as she was taken ill. The present condition of this patient is very much improved; the swelling of the arm is lessened, there is some edema however, of the forearm and hand. I am debating whether to employ the Beck principle to connect the lymphatic channel of the forearm with the arm or to use several cotton crochet threads or nylon strips, as advocated by Hapdley and Ranschoff (Fig. 6).

Case 4.—A female, 57 years old, had had a radical mastectomy performed in this hospital in December, 1936, for carcinoma of the breast. Roentgenotherapy was administered postoperatively. The left arm became somewhat swollen late in 1938, and, Septem-

FIG. 7-A

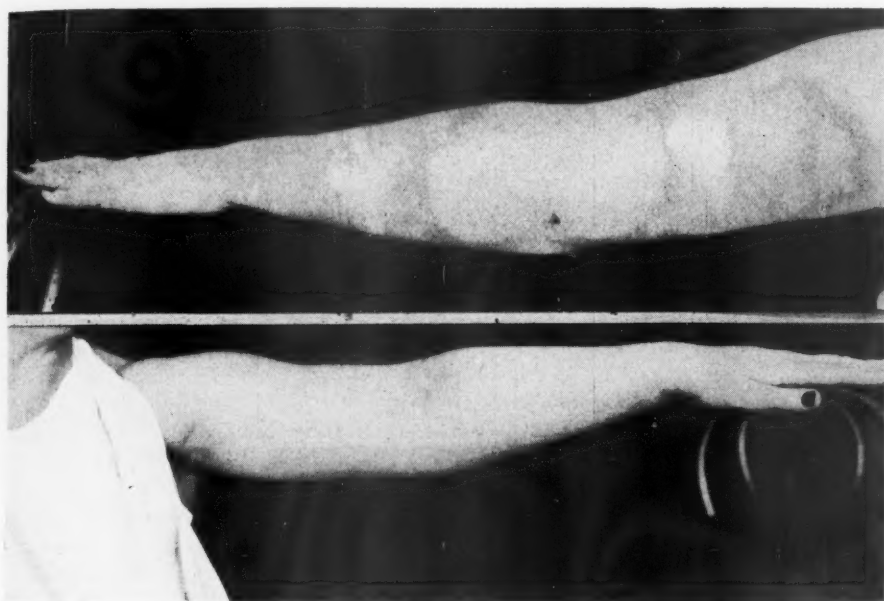


FIG. 7-B

FIG. 7-A—Case 5: Preoperative.

FIG. 7-B.—Case 5: Postoperative.

ber 19, 1939, she was readmitted to the hospital, the diagnosis being postoperative lymphedema. She had no complaints other than pain in this arm. There was no cough and no dyspnea. At this time, there was no roentgenographic evidence of recurrence of the carcinoma and, September 26, 1939 the Beck operation was performed. The celloidin strips were removed in three weeks, and the patient was discharged, much improved. At the time of a reëxamination in this Clinic in April, 1940, the patient's arm was still considerably less swollen than before the operation for the edema, but a roentgenologic examination revealed extensive metastatic pulmonary involvement. A notice of her death, at home, reached us some months later.

Case 5.—A 49-year-old, white female had had a radical mastectomy performed in this Clinic, January 6, 1944, for adenocarcinoma of the left breast. The wound healed *per primam*, and postoperative convalescence was uneventful. Roentgenotherapy was administered postoperatively. Within a few months after operation she developed swelling

of the arm, forearm and hand. The edema increased markedly and became brawny in nature. Chest roentgenograms failed to reveal any metastasis to the lungs, and no axillary recurrence could be detected. On July 25, 1945, a Beck operation was performed. In addition to the celloidin strips, two long cotton sutures, as advocated by Handley and Ransohoff, were buried underneath the skin extending from the wrist to the chest wall. The arm was kept elevated in an aeroplane splint. Two weeks later the celloidin strips were removed and the patient was discharged. At the time of her discharge the edema had subsided a great deal. The patient was seen recently, at which time the arm still remained practically normal in size. This patient is happy and is able to attend parties and do her housework (Fig. 7).

Case 6.—A 63-year-old, white female had had a radical mastectomy performed elsewhere six years ago for carcinoma of the right breast. Roentgenotherapy was administered postoperatively. One year after operation she was given another course of roentgenotherapy over her axilla for a questionable axillary recurrence. She developed a very



FIG. 8-A



FIG. 8-B



FIG. 8-C

FIG. 8-A.—Case 6: Preoperative.

FIG. 8-B.—Case 6: Preoperative.

FIG. 8-C.—Case 6: Postoperative.

marked swelling of the right arm, of the brawny type, nonpitting. The limb was four pounds heavier than the opposite one, on admission to the Guthrie Clinic. No evidence of recurrence of the cancer could be demonstrated. On August 31, 1945, the Beck operation, with additional burial of cotton sutures, was performed. The arm was kept elevated in an aeroplane splint and within a few days a definite shrinkage of the arm was noted, and was confirmed by measurements. The celloidin strips were removed three weeks later. The patient was submitted to a second Beck operation eight weeks later, hoping to further improve the result. She is still under treatment, and while the arm is much less swollen, the leathery changes in the skin of the axilla and the chest wall are so extensive that it is doubtful just how much further improvement can be obtained (Fig. 8).

COMMENT.—Postoperative lymphedema is a distressing but fortunately a

rare complication following radical mastectomy. When of severe degree, it is a crippling, painful and disabling condition. As a matter of fact, some patients have suggested amputation to rid themselves of the disability, the pain and the annoyance.

With such a limited amount of clinical data available it is as yet impossible to draw any definite conclusions concerning the value of the Beck operation in the treatment of lymphedema. Because so very few of our cases develop postoperative lymphedema, we are convinced that the measures we have outlined to prevent its occurrence have merit. This paper will accomplish its purpose if it stimulates interest and further research in this serious and disabling condition.

SUMMARY

Certain measures of prevention are described which the authors believe protect the patient from developing postoperative lymphedema.

No definite conclusions can be drawn from so meager an experience, and from the treatment of so few cases. The authors believe, however, because of the infrequent occurrence of arm edema in their cases that the position they take in regard to its prevention is correct.

The Beck operation has relieved a few of our patients, and because it is so simple and safe to perform it should be given a thorough trial.

REFERENCES

- Beck, W. C.: Quoted by Guthrie and French.
Devenish, E. A., and Jessop, W. H. G.: *Brit. J. Surg.*, **25**, 261, 1937; *idem.*, *ibid.*: **28**, 222, 1940.
Gray, J. H.: *Brit. J. Surg.*, **26**, 462, 1939.
Guthrie, Donald, and French, E. A.: *Guthrie Clin. Bull.*, **12**, 45, 1942.
Halsted, W. S.: *Bull. Johns Hopkins Hosp.*, **32**, 309, 1921.
Handley, W. S.: *Lancet*, **1**, 783, 1908.
Holman, C., McSwain, B., and Beal, J. N.: *Surgery*, **15**, 757, 1944.
Hooker, D. R.: *Am. J. Physiol.*, **28**, 235, 1911.
Ransohoff, J. L.: *Arch. Surg.*, **50**, 269, 1945.
Reichert, F. L., and Bidgood, C. Y.: Quoted by Halsted.
Standard, Samuel: *ANNALS OF SURGERY*, **116**, 816, 1942.
Veal, J. R.: *J. A. M. A.*, **108**, 1237, 1937; *idem.*: *S. G. & O.*, **67**, 752, 1938.

DISCUSSION.—DR. CHARLES GORDON HEYD, New York, N. Y.: Doctor Guthrie draws attention to a postoperative complication following a radical mastectomy which is often passed over. I believe that there will always be some lymphedema of the arm after radical resection, and it is due to cicatricial contraction around the axillary vein. For many years I have retained the pectoralis minor and, after careful dissection of all vessels and fascial attachments, have wrapped it under the axillary vein and sutured the distal end to the chest wall. We always leave the arm entirely free and encourage the patient to use the arm actively in every way possible while in the hospital. Instructions are given to continue stretching exercises at home.

I am sure that postoperative roentgenotherapy invariably increases the lymphedema of the arm. In two very severe cases I have employed the Handley operation of lymphangioplasty with considerable success in one, and only a fair result in the other.

DR. J. ROSS VEAL, Washington, D. C.: My interest in this subject came about from studying the venous circulation in patients with primary thrombosis of the subclavian vein. These studies included venograms and venous pressure determinations. In primary subclavian vein thrombosis the clot results from trauma and the surrounding tissues are free from inflammation. The pressure in the arm veins rises rapidly after formation of the thrombus and persists until adequate collateral veins form to relieve the venous congestion. We know that when the venous pressure in the arm is raised above 170 mm. of water, fluid is lost into the tissues, and the amount of edema is in direct proportion to the degree of elevation of the venous pressure. The average venous pressure in the acute stages of subclavian vein thrombosis is about 300 mm. of water.

The point of obstruction and the venous collaterals were easily visualized by venograms. Furthermore, it was shown that as the venous collaterals formed the pressure fell and edema subsided. By applying similar studies to some 60 cases of edema of the arm following radical mastectomy we found that venous thrombosis or venous obstruction was present in more than 90 per cent. Furthermore, the venous pressure in the arm was elevated sufficiently to produce edema. The cause of the venous occlusion may be scar tissue or recurrent malignancy.

One other factor that I think, often overlooked after radical mastectomy, is that the angle of the axillary vein is changed from an obtuse to a very acute angle when the arm hangs by the side. In this position the vein may be completely obstructed. Some relief for these patients may be obtained by carrying the arm away from the side. Ligation of a normal axillary vein at a single point is not likely to produce edema. If, however, sufficient tributaries are also blocked edema will develop.

Doctor Guthrie reports edema in 8 per cent of his cases, but I am sure the percentage will be higher in some hospitals. Infection, scarring and lymphatic blockage must play a part in some cases, but obstruction of the return venous flow is the most important factor in the production of edema.

REFRIGERATION ANESTHESIA FOR AMPUTATION*

FRANCIS M. MASSIE, M.D.

LEXINGTON CLINIC

LEXINGTON, KY.

THE PRINCIPLES outlined by Allen underlying the use of lowered temperature for the production of anesthesia in the extremities are now widely known and appreciated. Reference to the Quarterly Cumulative Index prior to 1941 shows no clinical reports on this subject; in 1941 there were three references; and in 1944 thirty-five.

The principles set forth by Allen as the result of his experimental work on animals are briefly: heat applied to tissue with an inadequate blood supply is an inexcusable menace because it increases the metabolism of the tissues so treated. This increased metabolism demands an increased supply of oxygen and tissue food and an increased circulation to remove the waste products and toxins of metabolism. Neither of these demands can be met and, therefore, tissue disintegration is hastened. Heat promotes the growth of bacteria and the further extension of infection and gangrene. Lowering the temperature of the tissues reduces the metabolism and, hence, decreases oxygen needs, diminishes absorption and formation of toxins and inhibits bacterial growth. Cold also produces anesthesia. This result was apparently an incidental finding, but was the main factor in the immediate clinical adoption of the refrigeration method.

The work of Allen¹ and others^{2,3} showed, too, that tourniquets could be applied for many hours or days with no harm to the ligated part or to the blood vessels in the constricted area if this part was immersed in ice water or placed in a pack of cracked ice.

At Allen's suggestion these principles were applied by the Surgical Staff of the City Hospital of New York, who reported in amputations for diabetic and peripheral vascular disease a reduction in fatality from 65 per cent to 15.5 per cent. This reduction in the number of deaths occurred in gravely ill, debilitated people, most of whom were over 60 years of age. This improvement they thought was due to the absence of shock during the operation and control of the degree and extent of the infection in the extremity involved. They also considered that the time spent in preparing the patient, which could never be spent prior to the introduction of the "ice method" but which thereafter became available, was valuable. We now believe that this together with control of infection afforded by the method are factors in reducing the death rate even more important than the absence of shock during the operation itself.

McElvenny⁴ has recently carried this preparation further by so-called "physiologic amputation" before surgery is performed. With a machine for maintaining and regulating low temperature (Therm-O-Rite) the affected

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

limb is frozen solid at a temperature of 10° F. and kept in this condition sometimes for as long as eight weeks. "During this time," he says, "they are comfortable, and the leg for all practical purposes is amputated." When the condition of the patient justifies it, whether this be eight hours or eight weeks, amputation is then done by surgery with or without tourniquet under any suitable general anesthetic. Cold is not continued after the operation.

It is interesting to note that the very factor in refrigeration, namely, anesthesia, which popularized the method and made it "catch on" so quickly, is now being relegated to a minor position,¹⁶ and properly so. It is possible that this freezing may eliminate the tourniquet except as an hemostatic agent. It is important to remember that all frozen tissue must at some later date be surgically removed, for in all such tissue the changes in the cells are irreversible, the cells are killed, while with the tourniquet and temperatures of 33° F. to 40° F. the cells are in "hibernation," all their metabolism has ceased and they are insensitive to stimuli. They return quickly to normal if the refrigeration and tourniquet asphyxia are not maintained for longer than 50 hours for the leg and thigh. The exact limits for the viability of human tissue under these conditions has not yet been determined but as clinical data continue to be recorded these limits will certainly be set. From our own experience we are sure that the limits will vary with the age of the patient subjected to the procedure. We will discuss this below when speaking of minor disadvantages and dangers of the refrigeration method. In those patients for whom amputation is certain the tourniquet and ice pack may safely be left on for days or weeks.^{1, 3, 4, 5, 6, 7} Where minor surgery is indicated such as amputation of a toe or finger, incision and drainage of an abscess of foot or hand, excision of an ingrowing toe nail, we have used the tourniquet and ice pack frequently without any damage to the temporarily asphyxiated tissue. Except in those where preparation is important, as in diabetics and patients with arteriosclerosis or cardiovascular disease, other methods of anesthesia are more suitable for minor surgery and much easier to use. But where preparation is so important we believe that the method should be used even in minor surgery as well as for amputations, not only for the control of infection but for the anesthesia as well.

We are in complete agreement with the opinion of McElvenny:⁴ "There is no need to hurry in any case and time is gained for the patient to rid himself of his toxins, to greatly improve generally, to be stabilized and built up to a point where he can stand a carefully selected general anesthetic and amputation with ease. In other words, a patient admitted in poor general condition with, for example, an infected gangrenous limb, diabetes, and who is somewhat disoriented, has in the writer's opinion the best chance of survival if infection is held static, absorption of toxins is prevented, and pain eliminated till (*sic*) the diabetes is controlled and the patient is oriented, active and cheerful. At this time, and only then, a general anesthetic by vein or inhalation or both is given and a planned deliberate operation performed.

"To take this same patient in, cool his limb for an hour or more after applying a tourniquet, and amputate as an emergency as soon as the cold has pro-

duced sufficient anesthesia by itself, does not appeal to this writer as sound surgical practice."

Lacking a Therm-O-Rite, or similar machine, we believe the proper method of applying the cold for major surgery is by ice pack and tourniquet for days or weeks, if necessary, then leaving this tourniquet in place and placing a second tourniquet at a high level after cooling for an hour the tissues at this higher level. After three to five hours of this second tourniquet with the limb returned to the ice pack, amputation is then done between the two constrictors. Many observers^{4, 7, 8} have used some modification of this method. Haley⁸ has devised a box with two compartments for icing the lower leg and the thigh for different lengths of time. We used a single compartment box for icing when we began but we found the box heavy, hard to handle, often leaky, and what was worse the lower margin of the hole in the upper end of the box, through which the thigh passed, often caused chafing and pressure discomfort

to the thigh at this point. We soon abandoned it for the better but not entirely satisfactory rubber sheeting. To those of us who have not tried it the ideal seems to be the controlled dry cold of the automatic machine.⁴ But this may seem ideal because we have not yet become acquainted with the possible temperament and vagaries of the machine. Until we are equipped with such apparatus the ice pack and rubber

TABLE I

MORTALITY OF THIGH AMPUTATION

Lexington Clinic Surgical Section

1932-1942 "pre-ice"	
Amputations, 72.....	Deaths, 12
Fatality, 16 2/3%	
1942-1945 "ice"	
Amputations, 30.....	Deaths, 5
Fatality, 16 2/3%	

sheeting with tourniquet will be fairly adequate if enough care is taken in applying the ice and tourniquet, seeing that the patient is dry and does not get out of the pack, examining the leg from time to time to be sure the tourniquet has not slipped, in short, in seeing that he receives adequate nursing.

The technic we have used for the past two years varies according to the severity of the illness. For minor surgery of the foot the patient sits for one hour with his foot or leg in a drum or deep bucket of cracked ice, the level of the ice coming to the knee well above the proposed site for the tourniquet. The rubber constrictor is then applied to the midcalf after blood is drained out by simple elevation for one minute. The foot (and leg) is returned to the ice for one hour and the patient brought to operation with his foot still in the bucket. After surgery, which is completely without pain, the tourniquet is removed, hemostasis carried out, and the wound closed or left open, depending on the nature of the disease for which the operation was performed. Ice bags are continued on the affected part for 24 hours if there has been no infection and longer if the operation has been for abscess or gangrene.

Patients with more extensive gangrene and infection, who are well oriented, in good condition, and if diabetic, the sugar metabolism is under control, we put in bed with the foot, leg and thigh in a pack of cracked ice for one hour. The ice is in direct contact with the skin. Seconal gr. 1.5 is given one-half hour before this. The ice pack consists of rubber sheeting on which is placed a layer of finely cracked ice, the limb is placed on top of this and covered on all

sides and on the anterior surface with a thick layer of cracked ice. The amount necessary varies between 50 and 100 pounds. The rubber sheeting is wrapped around the limb and must be long enough so that its "snout" protrudes through the bottom of the bed. When the head of the bed is raised the water drains into a bucket on the floor placed under the "snout." The ice extends almost to the groin (or axilla). After one hour of this the limb is raised from the pack, the tourniquet is applied to the upper thigh (or arm) and the limb returned to the pack. This is maintained for four hours. From time to time the pack is opened, the ice scraped away and the skin examined. If there is any discoloration or mottling, the tourniquet is removed and replaced more tightly, for the discoloration means a leaking tourniquet and a leaking tourniquet means incomplete asphyxia and insufficient anesthesia. Attempting to determine the efficacy of the tourniquet by feeling for the pulse is futile, as we have never been able to feel pulsation below a badly leaking constrictor.

Recently we have done two operations of midthigh amputation where the tourniquet was leaking and where anesthesia was perfect. In both instances the limb had been in the pack five hours.

The patient is brought to the operating room on a stretcher still in the ice pack; he is lifted out of the pack and the limb is prepared and amputation done without further anesthesia unless the procedure for some reason is obviously causing pain. If this proves so, the operation is continued under nitrous oxide or cyclopropane. Four of our patients have had this supplementary inhalation anesthesia. With two patients the ice pack had been removed by mistake just before the patients were placed on the stretcher to be taken to the operating room. In neither instance was the complete anesthesia affected.

Patients who are more severely ill from infection, diabetes or both, we treat with the ice pack as outlined above but without the tourniquet and with the ice limited to the area below the knee. This pack is kept on for days. Care is taken in elderly sclerotic people to limit the ice to tissues which will be amputated later because we have had three patients, Cases 18, 19 and 28 (Table II), 81, 77 and 72 years old, respectively, none of whom had diabetes, who received "frost bite," with subsequent sloughing of the skin of the thigh in the area above the amputation. The ice had been in contact with the skin of one, Case 18, only 45 hours, of Case 19, 96 hours, and Case 28, 72 hours. This varies from the experience of others.^{4, 6, 8} McElvenny,⁴ in discussing the question of how long normal skin can stand the application of ice without disintegration cites one patient, 70 years old, who suffered no skin injury from ice contact for 28 days though his skin was then removed with the part amputated. No tourniquet was used. Another patient, 69 years old, with considerable arteriosclerosis was injured, and after unsuccessful chemotherapy and severe infection in the leg developed was placed in the ice pack without tourniquet for eight weeks. Two days after the ice pack was begun split-skin grafts were used on the raw area. After eight weeks the grafts were growing well and there was no injury to the normal skin.

In spite of this and because of our own experience with three patients we

TABLE II
AN ANALYSIS OF ALL THIGH AMPUTATIONS PERFORMED UNDER "ICE ANESTHESIA"

Race	Sex	Age	Diagnosis	General Condition	Wound	Anesthetic	Result
1. W	F	73	Diabetes, with gangrene, severe	Poor	Infection 4 plus		Good. Hosp. days, 69. Preop. days, 8
2. W	F	66	Diabetes with gangrene	Good	Primary healing		Good. Hosp. days, 20. Preop. days, 4
3. W	F	75	Sarcoma foot	Good.	Primary healing		Good. Hosp. days, 19. Preop. days, 1
4. W	M	67	Diabetes, with gangrene, severe	Fair. B. P. 190/80 B. P. 136/80	Primary	Ice plus N ₂ O	Poor. Hosp. days, 63. Preop. days, 37. Died 3 months. Autopsy ca. pancreas; not in mortality % Good. Hosp. days, 36. Preop. days, 5 Good. Hosp. days, 28. Preop. days, 6 Good. Hosp. days, 38. Preop. days, 18
5. C	F	56	Diabetes, with gangrene, severe	Fair. B. P. 164/76	Infection 4 plus		Good. Hosp. days, 36. Preop. days, 5
6. W	M	73	Diabetes, with gangrene	Good. B. P. 200/106	Primary union		Good. Hosp. days, 28. Preop. days, 6
7. W	M	59	Diabetes	Good. B. P. 216/84	Primary	Ice plus N ₂ O	Good. Hosp. days, 38. Preop. days, 18
8. W	M	57	Diabetes, with gangrene	Good. B. P. 138/65	Healing primary		Good. Hosp. days, 19. Preop. days, 5
9. W	F	54	Diabetes, with gangrene, severe	Good. B. P. 170/90	Infection 1 plus		Good. Hosp. days, 28. Preop. days, 6
10. W	M	77	Diabetes, with gangrene	Good	Healing primary		Good. Hosp. days, 30. Preop. days, 6
11. W	M	57	Diabetes, with gangrene, severe	Fair	Infection 2 plus. Delayed healing		Good. Hosp. days, 77. Preop. days, 25
12. W	F	56	Diabetes, with gangrene	Good	Primary healing		Good. Hosp. days, 23. Preop. days, 6
13. W	F	66	Diabetes, with gangrene	Good. B. P. 138/76	Infection 2 plus	Ice plus N ₂ O	Good. Hosp. days, 22. Preop. days, 6
14. W	M	72	Diabetes, Cardiac	Poor. B. P. 230/110	Primary healing		Died. Hosp. days, 128. Preop. days, 10. Cardiac failure
15. W	M	75	Diabetes, with gangrene	Good	Primary healing		Good. Hosp. days, 31. Preop. days, 10
16. W	M	61	Diabetes, with popliteal aneurysm and gangrene	Good. B. P. 190/110	Primary healing		Good. Hosp. days, 17. Preop. days, 1

TABLE II—(Continued)
AN ANALYSIS OF ALL THIGH AMPUTATIONS PERFORMED UNDER "ICE ANESTHESIA"

Race	Sex	Age	Diagnosis	General Condition	Wound	Anesthetic	Result
17.	W	M	70 Arteriosclerosis, gangrene	Good. B. P. 170/80	Delayed healing, with secondary closure		Died. Hosp. days, 115. Preop. days, 47. No permission for amputation until 1 day preop.
18.	W	F	81 Arteriosclerosis, gangrene	Good. B. P. 190/100	Slough of thigh skin. Ice contact 45 hours preop.	Cardiac	Good. Hosp. days, 80. Preop. days, 10
19.	W	M	77 Arteriosclerosis, trauma	Good	Slough of thigh skin. Ice contact 4 days preop. Delayed healing		Good. Hosp. days, 110. Preop. days, 10
20.	W	F	66 Diabetes, with gangrene, severe	Good	Gas bacillus infection		Good. Hosp. days, 45. Preop. days, 6, 3 operations
21.	W	M	56 Arteriosclerosis, gangrene	Poor	Primary healing		Good. Hosp. days, 45. Preop. days, 3
22.	C	F	65 Arteriosclerosis, with heart disease and congestive failure	Poor. B. P. 190/110			Died 3rd postop. day. Heart. Preop. days, 6
23.	C	M	73 Arteriosclerosis, with gangrene	Poor. B. P. 240/120. Cong. failure			Died 2nd postop. day. Heart
24.	W	M	60 Sarcoma (melano) foot	Good, but	Primary healing		Good. Hosp. days, 13. Preop. days, 3
25.	W	M	75 Arteriosclerosis, gangrene	B. P. 220/110 Poor. Hb. 37%.	Primary healing		Good. Hosp. days, 28. Preop. days, 3
26.	W	M	25 Osteogenic sarcoma leg	B. P. 160/105 Excellent	Primary healing		Good. Hosp. days, 20. Preop. days, 7
27.	W	F	68 Diabetes, severe	Poor	Primary healing		Good. Hosp. days, 47. Preop. days, 20 (same as Case 20)
28.	W	M	72 Arteriosclerosis, 4 plus	Poor. B. P. 190/115	Skin slough after ice contact of 72 hours		Died at home 3 months postop. Heart
29.	W	M	68 Diabetes, with gangrene	Fair. B. P. 190/85	Primary	Ice plus cyclo.	Good. Hosp. days, 21. Preop. days, 5
30.	W	F	66 Diabetes, with gangrene, severe, foot and lower leg. Temp. 102° F.	Good. B. P. 130/90	Infection 2 plus	Ice plus N ₂ O	Good. Hosp. days, 42. Preop. days, 17

follow either one of the following variations: When the patient is not severely ill and where amputation is not certain we follow the advice of our senior partner, Dr. W. O. Bullock, and cover the affected part with ice bags to lower, but not stop, the metabolism in this area. A similar idea is suggested by Allen,⁷ who advises in such cases an electric fan to keep the skin of the affected part between 68° and 86° F. At the same time "an accurately controlled heating device is applied from the thigh down below the ankle and maintained at the highest safe temperature, in order to promote hyperemia." This nicely balanced point between heating and chilling seems to us beyond the powers and equipment of the average clinician and we shall continue to use ice bags of thin rubber and possibly add, at Dr. Allen's suggestion, the electric fan.

For the severely ill debilitated wrecks we shall continue to use the two-tourniquet plan. The leg is "amputated physiologically" with a tourniquet below the knee and the leg is kept in ice for whatever time may be necessary for the restoration of the patient's full balance—often this is days or weeks. Of course, permission for amputation must be obtained from the patient or responsible members of his family. When the patient is ready for operation the further course is the same as that for ordinary thigh amputation, namely, ice pack on thigh for one hour, then tourniquet around upper thigh, then return to the ice pack for four hours, followed by mid or low thigh amputation without further anesthesia. The distal tourniquet below the knee, which has been on for days or weeks, is not removed until salvaged from the amputated part.

It is still almost unbelievable to see one of these old, sick people brought to surgery and a midthigh amputation performed with no pain, no fall in blood pressure, no rise in pulse rate, while patient and anesthetist are carrying on a lively conversation. The patient eats a normal breakfast, takes the usual dose of insulin if necessary, and returns to bed and continues his regimen of insulin and diet without any change because of his operation. We close the wound tightly, with one gram of sulfanilamide crystals under the muscle flaps. We use a fish-mouth incision and do not inject the sciatic nerve with alcohol. We use plain catgut throughout, chiefly No. 00 in size, and close the skin with interrupted and continuous sutures of silk. The rubber ice bags are kept on the stump for four to six days and patients are encouraged to be up in a wheel chair the day after the operation. Because healing is slow sutures are not removed for 12 or 14 days unless infection develops in the stump.

The advantages of the "refrigeration method" may be briefly summarized. This procedure almost instantly relieves pain in the affected part; limits the activity and spread of infection; prevents the absorption of toxins from bacteria and tissue; suspends the diseased process until the severely ill patient can be restored to balance by the many and varied means he may require; and in severe trauma and shock^{5, 6, 7} not only combats the shock itself but saves anemic and potentially infected tissue otherwise lost by preserving it until collateral blood supply develops, as attested by the work of Mock and Mock.⁸ It widens the range of operability to include those gravely ill patients who here-

tofore have been considered hopeless, too far gone for surgery, most of whom under this regimen recover.

It is important to note, here, that refrigerated asphyxiated tissue does not have to be removed if it is not actually frozen and, hence, the method may be used for any operation on the extremities where no amputation is indicated.

Its increasing use for a wide variety of conditions was predicted, and is now being realized in many quarters. It has been used to postpone, and even make unnecessary, débridement in trauma and in burns⁷ where it is especially useful in controlling the pain of repeated dressings. "Tedious operating room asepsis" becomes unnecessary because the cold controls infection. Carefully controlled moderate, not radical, refrigeration is now being used in frost-bite and "exposure" gangrene; the preservation of skin grafts;^{4, 9, 15} the treatment of various types of insect and venomous snake bites⁷ (without tourniquet); and for sudden thrombosis and embolism in the extremities.

In our own experience, we are using the cold pack without tourniquet more and more in the treatment of major and minor infections of the hand and foot, with and without incision and drainage. The case in the care of our colleague, Dr. Allen Grimes, of Lexington, and reported here with his permission, illustrates dramatically the value of ice and tourniquet in a severe gas bacillus infection:

Case Report.—A white woman, 57 years old, was admitted to St. Joseph's Hospital June 4, 1944 in the care of Dr. W. M. Brown with a compound fracture of the left tibia 12 hours before admission. Her condition on admission was good, temperature 100° F., pulse 90, blood pressure 130/85. The wound showed no gross evidence of infection and no cellulitis. Ten hours after admission the wound was scrubbed with soap and water, dirty tissue cut away and after reduction of the fracture a stay screw was used to hold the ends in place. This was done by Dr. Brown, and a plaster jacket applied including the foot and knee. Five hours later the patient had temperature 105° F., chill, pulse 120, and shortly thereafter became irrational. The encasement was removed, the foot was swollen and blue. The discolored area, with edema and crepitation, was extending up to the calf. Gas could be expressed from the wound. A tourniquet was applied just below the knee and the leg was packed in ice. Eight hours later the patient was rational, temperature 100° F., pulse 80, and there was no extension of infection above the tourniquet. After 22 hours in the ice pack with tourniquet Dr. Grimes performed a mid thigh amputation under general anesthesia (nitrous oxide) leaving the stump open. The wound was closed after nine days, and she left the hospital three days later, without further incident.

The disadvantages of the method are small compared to the literal saving of life and limb to which so many observers now attest. They may be listed for discussion:

1. The method is "sloppy" and difficult to carry out, troublesome and time-consuming. Merely to state this objection is to answer it, because this same objection can be raised to a great many valuable procedures now accepted and carried out as a matter of routine. Furthermore, the increasing use of automatic cooling machines, soon to be available, will remove much of the drudgery and "sloppiness" of the preparation.

2. The anesthesia may be ineffective, and supplementary general anesthesia

may be necessary when the patient has had food recently. This very minor disadvantage may be avoided by a good tourniquet efficiently applied and by keeping the limb in the pack long enough, four to five hours, before the operation. Furthermore, as the anesthesia produced by cold is now not the most important result of the method, all patients may be prepared for general anesthesia.

3. Ice in contact with the skin of old people may cause subsequent sloughing in skin which should not have to be removed, as it did with three of our patients, above the line of amputation. This might occur also where there is extensive trauma in old people where amputation will not be necessary but where cold is used to limit infection and allow collateral circulation to develop. This difficulty may perhaps be obviated by using the ice in thin rubber bags instead of in direct contact and with the addition of the electric fan. It is probable that machines will so regulate lowered temperatures that we may determine what the skin visibility limits are for each patient.

4. The lower tissue temperature delays healing. This may be met simply by leaving the sutures in longer. It is not yet certain that healing is delayed as skin grafts⁴ have been found to grow well with lowered temperatures.

5. The most important objection raised so far is that resistance of tissue is so lowered by the prolonged cold that infection is more likely to take place, and to be more serious when it occurs, after the temperature has been returned to normal. This objection has been raised by Brooks and Duncan,¹⁰ Large and Heinbecker,¹¹ and Richards,¹² and answered by Allen and by Crossman,¹⁴ and is still unsettled. Even if tissue resistance to infection is lowered by cold, and this is not proved, it is a minor risk compared to the enormous advantages and a risk all are willing to assume who have personally seen patients get well who previously would have died without surgery because the risk of an operation would have been too great.

The death rate in our series (see Table I) for 72 cases is 16% per cent compared with 16% per cent in cases during a ten-year period preceding the "ice" method.

What the statistics do not show is that in the "ice series" no patient was turned down because of the severity of the illness or hopeless condition of the individual. There are fewer wound infections; hospitalization is shorter; and the patients are more comfortable.

An analysis of our six deaths may be of value. In Table II we have listed only those with thigh amputation:

Case 4, a white male, 67 years old, with gangrene of the foot and severe diabetes, had a good result so far as his anesthesia, healing of his stump, and recovery from the operation are concerned, but succumbed three months later from cancer of the pancreas, with liver and peritoneal metastases shown at autopsy. For this reason we have not included him in our death percentage.

Case 14, a white male, 72 years old, had hypertensive heart disease with congestive failure who died of his cardiac condition on his second admission to the hospital four months after his operation. We have included him in our

death percentage because he died from a condition the operation was designed to improve.

Case 17, a white male, 70 years old with arteriosclerotic gangrene and ascending infection, died two months after his operation from cardiac congestive failure. He was in the hospital 46 days before permission was granted for amputation and was in the ice pack without tourniquet six days before operation. This cannot be classed as a preventable death.

Case 22, a colored female, 65 years old, died on the third day after operation from congestive heart failure. This was a poor risk "heart" patient who might have been saved with the "two-tourniquet" method described above. She had marked arteriosclerosis with a gangrenous foot and was kept in the ice pack only two days before operation.

Case 23, a colored male, 73 years old, with arteriosclerotic gangrene of the foot and hypertensive heart disease, died two days after the operation of heart failure. This was a desperately ill old man who possibly could not have been saved by any method. He should have had the advantage of the two-tourniquet method and longer preparation.

Case 28, a white male, age 70, with marked arteriosclerosis and spreading gangrene of the foot. He was kept in the ice pack without tourniquet three days before operation. Except for sloughing of the skin of the stump, which exactly followed the area of contact with the ice, even above the tourniquet, his wound healed well. He was always disoriented, required a catheter and forcible restraint, and was fed by gastric tube for three weeks. He died at home three months after the amputation. He never regained his mental clarity and was always helpless. It is unlikely that any method of treatment would have saved this patient.

It is noteworthy that of our six deaths only two of the patients had diabetes, in neither of whom was this disease a factor (Cases 4 and 14); while of 11 patients without diabetes, there were four deaths, seven of these had marked arteriosclerosis with hypertensive heart disease, and the four deaths occurred in this group. In our series of 19 patients who had diabetes there were only two deaths (Cases 4 and 14)

SUMMARY

1. Experimental and clinical work have shown that living tissue is viable when completely asphyxiated (with tourniquet) for many hours if the temperature is kept between 33° and 40° F.
2. Where the tissue is to be removed later (by amputation) this time may be extended to many weeks if necessary.
3. This method of cooling tissue by an ice pack, with or without a tourniquet, stops pain, controls and prevents the spread of infection in an extremity until the patient is properly prepared for surgery.
4. No patient is too hopeless for surgery when prepared by this method.
5. In trauma and embolism (arterial) the ice pack without tourniquet pre-

REFRIGERATION ANESTHESIA

serves the tissues of the extremity until collateral circulation develops which may make amputation unnecessary.

6. It is useful in minor surgery with the tourniquet where no tissue is to be removed.

7. There is possible danger that cooling may lower the resistance of tissue so that infection occurs more frequently and spreads more rapidly when normal temperatures are restored.

8. A number of uses for the procedure may be found such as the treatment of shock, burns of the extremities, insect and snake bites, and the preservation of skin grafts.

9. It produces complete anesthesia when properly applied so that operation may be carried out without any shock to the patient or interference with his diet and insulin requirements.

10. Anesthesia is minor in importance when compared to the value of careful and thorough preparation of the patient which the method affords.

REFERENCES

- ¹ Allen, F. M.: S. G. & O., **67**, 746-751, 1938.
- ² Crossman, Ruggiero, Hurley and Allen: Arch. Surg., **44**, 139-156, 1942.
- ³ Brooks and Duncan: ANNALS OF SURGERY, **112**, 130-137, 1942.
- ⁴ McElvenny, R. T.: Surg. Clin. N. A., **25**, 192-209, 1945.
- ⁵ McElvenny, R. T.: S. G. & O., **73**, 263-264, 1941.
- ⁶ Mock, Harry E., and Mock, Harry E. Jr.: J. A. M. A., **123**, 13-16, 1943.
- ⁷ Allen, F. M.: Am. J. Surg., **68**, 170-184, 1945.
- ⁸ Haley, E. R.: Arch. Surg., **46**, 518-524, 1943.
- ⁹ Mock, H. R. Jr.: J. A. M. A., **122**, 597-598, 1943.
- ¹⁰ Brooks and Duncan: ANNALS OF SURGERY, **114**, 1069-1075, 1941.
- ¹¹ Large, A., and Heinbecker, P.: ANNALS OF SURGERY, **120**, 707-749, 1944.
- ¹² Richards, V.: ANNALS OF SURGERY, **119**, 178-200, 1944.
- ¹³ Allen, F. M.: Anesth. & Analg., March-April, 1945.
- ¹⁴ Crossman, L. W.: Cited by Allen.⁷
- ¹⁵ Webster, J. P.: ANNALS OF SURGERY, **120**, 431-449, 1944.
- ¹⁶ Johnston, C. G.: Am. Jour. Med. Sc., **209**, 253-257, 1945.

VERTICAL TRACTION: AN AID IN THE SURGICAL MANAGEMENT OF CERTAIN LARGE TUMORS*

CASE REPORT

W. O. BULLOCK, M.D.

LEXINGTON, KY.

Case Report.—The patient, Mrs. R. B., first came under my observation October 1, 1943. At that time she presented an enormous tumor which hung down from her right buttock and reached the lower limits of the popliteal space. She stated that the growth



FIG 1.—Appearance of the tumor.

first appeared at the age of five like a birthmark and has continued to grow until it reached its present dimensions. The growth extended over the buttock; the involved area reached the level of the iliac crest. Several smaller off-shoots of the mass projected across the midline, as seen in the illustrations. There were no symptoms associated with the growth, nor was her health in any way impaired. She moved about with difficulty on account of the size of the pendulous mass.

A former attempt to remove the growth had been made elsewhere, but the operation had to be discontinued on account of massive bleeding the patient states.

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

VERTICAL TRACTION



FIG. 2.—Position of patient for operation.

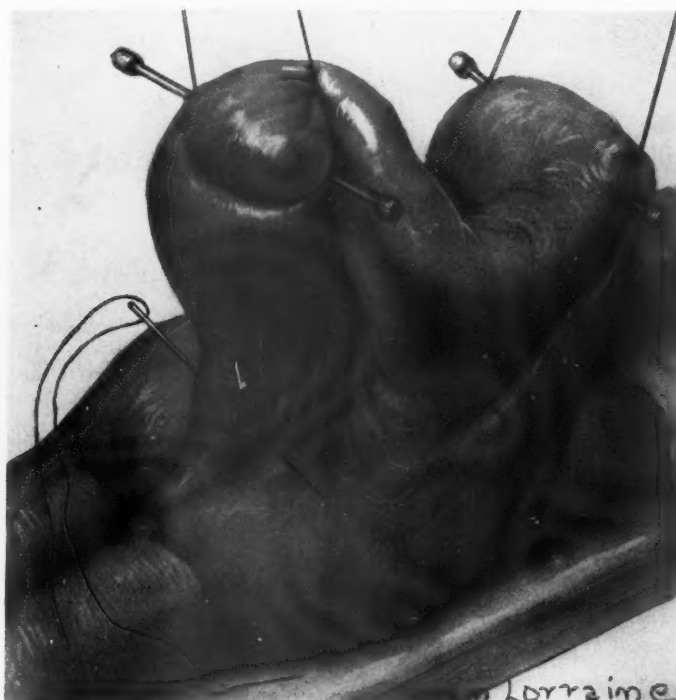


FIG. 3.—Showing elevation of the mass with use of overhead pulleys and long mattress needle for mattressing base to control bleeding.

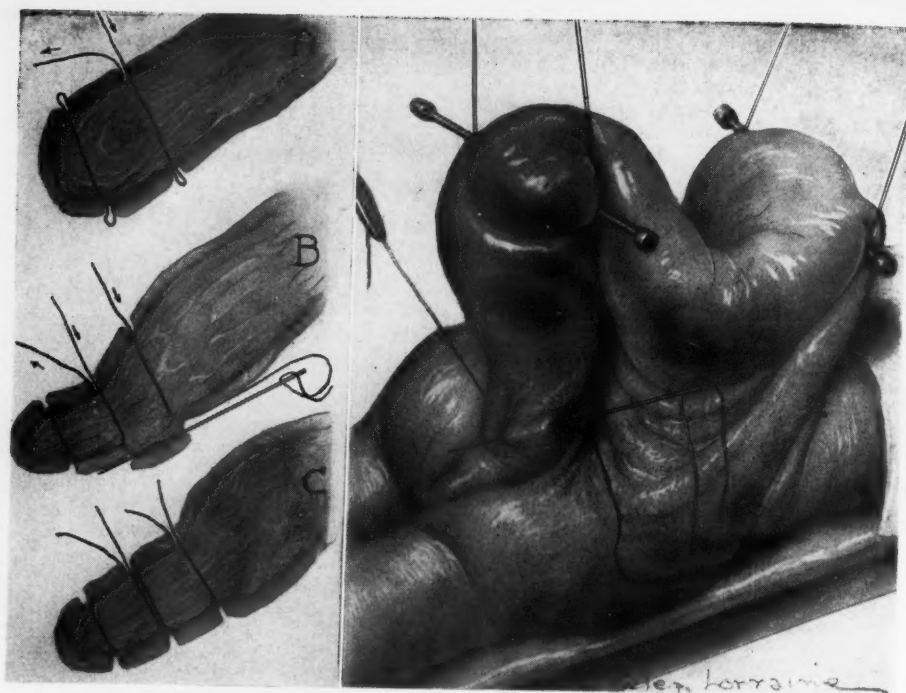


FIG. 4.—Showing procedure for constricting base.

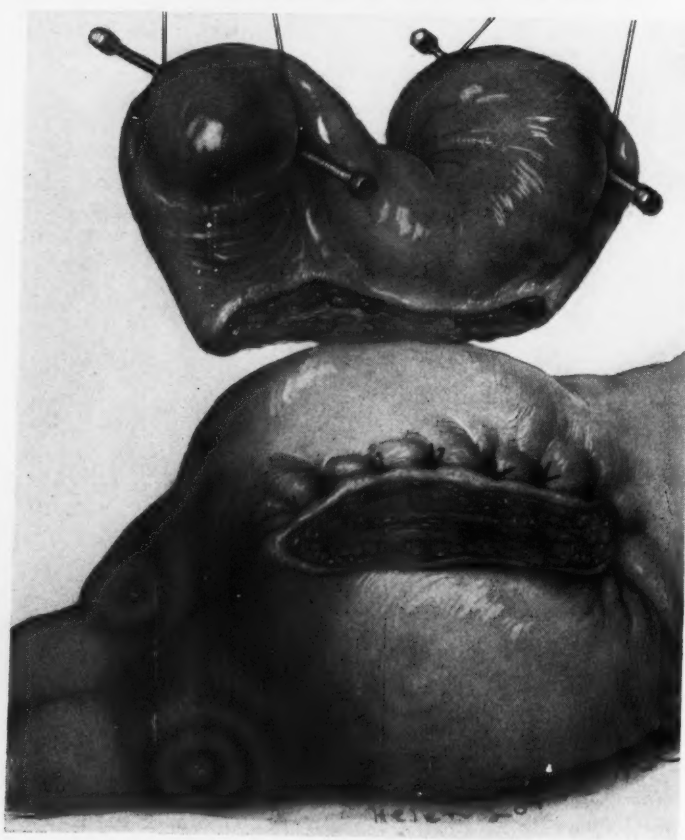


FIG. 5.—Removal of the tumor.

VERTICAL TRACTION

Complete removal of the tumor was obviously impossible but if the dependent part could be removed, it would permit ambulation in a normal manner—at least for a period. The problem was, therefore, one of hemostasis, and preliminary control of hemorrhage until the work could be accomplished. To get at the base of the mass it had to be lifted and held up out of the way. The preoperative diagnosis was hemangioma or lymphangioma.

Operation.—October 10, 1943: Under gas-oxygen anesthesia, the patient was placed face down on a Bell orthopedic table with overhead bars, the area was prepared by scrubbing and painting with merthiolate. Two Wyeth pins were pushed through the tumor close to its most dependent limits, sterile bandages were attached to the pins and then carried to two pulleys attached to the overhead bars of the table, the mass was then elevated away from the body leaving the base free; the area was then resterilized and draped. For control of the bleeding it was decided to mattress the base without strangulating the skin, using a long mattress needle with heavy netting cord. The needle was pushed through the base through the skin on the opposite side, then reinserted, pushed beneath the skin to another opening, then back through the tumor, then beneath the skin to the point of starting. This included the tissues at the base for two or three inches. The procedure was repeated some five or six times until the entire base was included in the areas to be constricted. The sutures were then tied and removal of the tumor begun. The operation was almost bloodless until accidentally one of the constricting ligatures was severed. Massive bleeding took place, requiring six pints of blood for replacement. There was a great network of veins imbedded in the fat surrounding the tumor mass. Structurally the growth was a neurofibroma.

Three subsequent operations were performed on smaller projections of the tumor.

At the present time the mass is gradually slipping down, reaching the upper third of the thigh. How long it will take for the growth to reach its former dimensions I do not know—probably several more years.

The technic of overhead traction was found very useful in this case, and it is believed it will find a place in similar cases, and especially does it seem ideal for interscapulothoracic amputations.

These large growths suggest also that we are not using the remarkable ability of the skin to adapt itself to internal pressure and traction. I have in mind the possibility of producing artificial cysts, gradually increasing their size, or by traction of the skin gradually applied, thus, any amount of normal skin might be obtained for any conceivable defect.

DISCUSSION.—DR. CARRINGTON WILLIAMS, Richmond, Va.: I would like to thank Doctor Bullock for bringing this very ingenious method before the Association. I recall two tumors where I am sure this method would have facilitated their removal. The first was seen with Dr. William H. Goodwin, and I will never forget the amount of bleeding he had to deal with, but he removed it. The second was a retroperitoneal sarcoma weighing 54 pounds. If we had had this overhead traction I would not have been so tired after helping Dr. Stewart McGuire remove it.

DR. ISIDORE COHN, New Orleans, La.: I cannot miss the opportunity to mention a case Dr. Matas had about 20 years ago, a woman with Recklinghausen's disease who had one tumor that hung from her neck like a snood, weighing more than 100 pounds. The woman could not get around. He decided to take it off. He got a large pair of ice tongs, had a pulley and rope attached on the roof of the operating room, tied to the observation rails in the operating room, and he successfully removed it. It was one of the most remarkable things I ever saw. I do not know whether he used the prophylactic hemostatic sutures.

THE TREATMENT OF SEBACEOUS CYST BY ELECTROSURGICAL MARSUPIALIZATION*

JOSEPH A. DANNA, M.D.

NEW ORLEANS, LA.

FROM THE DEPARTMENT OF SURGERY, MEDICAL SCHOOL, LOUISIANA STATE UNIVERSITY, NEW ORLEANS, LA.

LIKE THE POOR, the sebaceous cyst we always have with us; and if we consult the textbooks, the treatment recommended is, invariably, simple but complete excision. Yet, in spite of the greatest care, rupture of the cyst during excision, and recurrence is not so rare. In such regions as the upper back, the firmness of the tissues makes good cosmetic closure of the resultant cavity after excision difficult, and the pull against the suture line of ordinary bodily activity, even in the reclining state, often results in pulling apart of well-placed sutures, and healing by granulation and scarring. On the face, the female breast and anterior chest surface, while the tissues lend themselves to good approximation, failure of primary union is not infrequent, resulting in tell-tale scars.

A report of the application of a new principle, or rather the use of an old one, to the cure of sebaceous cyst that seems to compare quite favorably in percentage of cures and cosmetic results, will perhaps not prove too trivial a matter to consider.

Last January, I reported 20 cases treated by this method.¹ I have treated 12 additional ones since. They were situated on the face, neck, scalp, back, breasts and surrounding areas, deltoid region and a high thigh amputation stump. They ranged in size from 1.5 to 6 cm. Nearly half were inflamed, about to rupture, or were associated with an adjoining abscess.

TECHNIC

A sharp needle is inserted into the center of the top of the cyst so that its point barely protrudes into the cavity (Fig. 1) and the diathermy current is turned on until a whitish eschar is seen to form around the needle. This takes from two to five seconds. If the needle is inserted too deeply the force of the current is dissipated in the cyst contents and no cauterization results. The diameter of the slough produced should be approximately one-fourth that of the cyst itself. One puncture is sufficient with cysts up to about 3 cm. in diameter. Two or three adjacent punctures will be required with the larger cysts. The center of the top of the cyst is the preferred point of puncture, for here the combined thickness of skin and cyst wall is thinnest, there being no fat or areolar tissue intervening. A puncture away from the center would result in a much thicker slough with the possibility that cicatricial closure might

* Read before the Fifty-seventh Annual Session of the Southern Surgical Association, December 4-6, 1945, Hot Springs, Virginia.

THE TREATMENT OF SEBACEOUS CYST

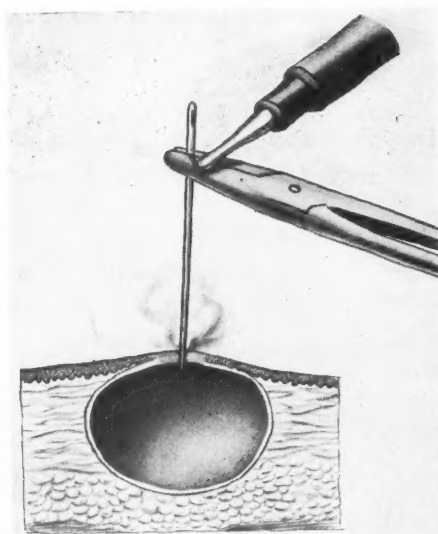


FIG. 1.—Insertion of the needle and application of the electrode as the current is turned on.

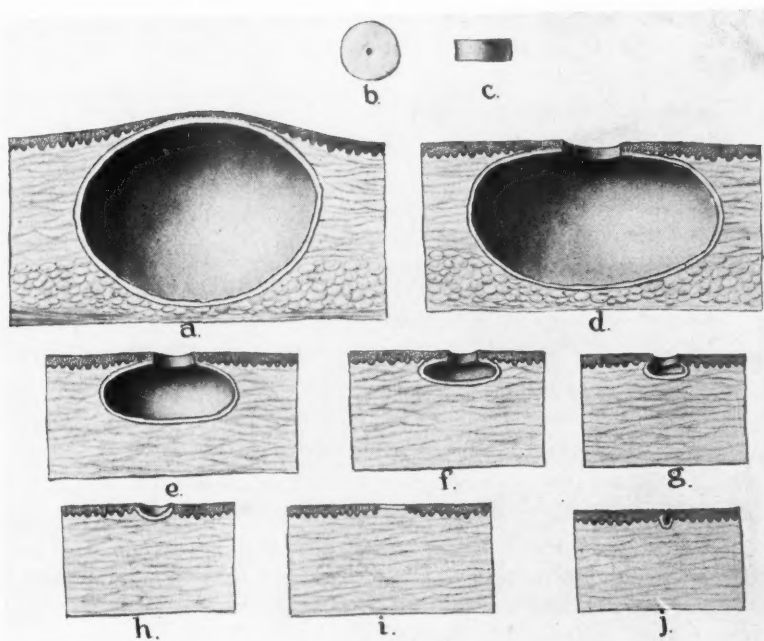


FIG. 2.—(a) Section of intact cyst.
(b) Superficial view of button of tissue which sloughs out.
(c) Lateral view of (b).
(d) Cyst after slough has separated.
(e, f, g, h) Various stages of diminution in size of cavity.
(i) Final leveling off of cyst wall, the usual result in uncomplicated cases.
(j) The result in six cases following previous excision or preoperative inflammation and infection.

ensue before skin and cyst wall epithelium had time completely to cover the entire edge of the resulting opening. Where the cyst has become infected and possibly ruptured into the surrounding fat, it may be difficult to judge just where the thinnest area over the cyst proper actually lies. The needle may be inserted into an adjacent pus cavity (Fig. 3a) in which case the opening will promptly close, necessitating a second treatment with the needle properly placed. The unipolar desiccating current of the office diathermy machine was used for the smaller lesions and the bipolar coagulating current from the same machine for the larger ones. The current is barely strong enough to produce the necessary desiccation or necrosis, the patient experiencing a sharp stinging

sensation that is easily borne for the few seconds required. In only three nervous individuals was it necessary to use a 1 per cent procaine injection in the surrounding skin.

At the end of five to eight days a button of necrotic tissue sloughs away, leaving an opening the surrounding edges of which are firm, indurated, and the margins inflamed.

In the course of the next three to six weeks, the cyst gradually empties itself, the cavity gets smaller and smaller till the bottom of the cavity finally presents on the surface and soon levels off in a straight line with the surrounding skin showing as a pigmented area which later assumes all the qualities of the skin. There is no drainage of any consequence during this time. In about one-third of the cases there was a tendency for this pigmented area to dimple, reverting as it were to the original shape of the sebaceous gland from which it sprang,

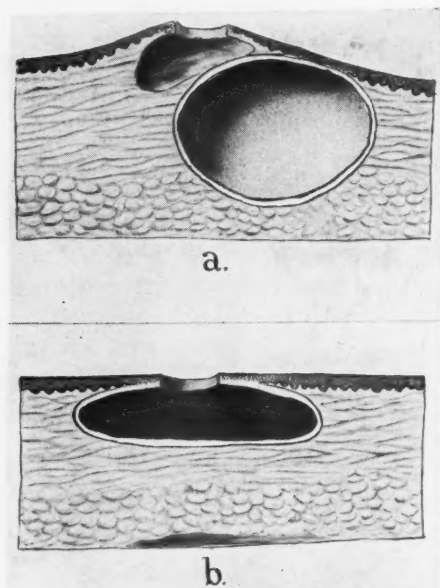


FIG. 3.—(a) The result where the needle was inserted over the top of an adjacent abscess.

(b) Persistence of cavity in case in which hard mass of inspissated cells had to be forcibly squeezed out before cavity diminished in size and finally closed.

resulting in what looks like a large blackhead which is easily kept empty and clean. This latter condition nearly always resulted when the cyst had recurred in an old scar, or where rupture from infection had occurred or was imminent at the time of treatment. In two instances this dimple was quite marked and definitely unsightly. It is hoped that further experience will enable us to avoid a repetition of such a result. In two cases the contents of the cyst were hardened into a compact mass and had to be squeezed out forcibly before the cavity would close.

A glance at Figure 1 will show that the tissue margin at the line of separation after the disk of necrotic tissue has separated is very thin. During the

THE TREATMENT OF SEBACEOUS CYST

few days required for this separation there is considerable inflammatory infiltration of the tissue surrounding the line of demarcation so that when the slough separates the surrounding tissue is rigid and has no tendency immediately to permit the opening to diminish in size.

There now ensues a race between the tendency of the opening to cicatrize in a circular manner and close, on the one hand, and of the epithelium of the skin and that of the cyst wall to bridge the thin edge of the circular opening, on the other hand. Since the distance to be covered by the two advancing lines of epithelium is very short, the epithelium wins out, and once the entire circumference of the opening is covered with epithelium there is then no further tendency to cicatricial closure of the opening. Meanwhile, the contents of the cyst are free to drain out and actually do so. But what is most remarkable is the fact that in the uncomplicated case the cyst cavity gets smaller and smaller till the bottom of the cavity finally presents on the surface and straightens out in a straight line level with the skin, and takes on all the qualities of skin (Fig. 2 a, e, f, g, h, i). How this is brought about I find it hard to understand, for some of these cavities were 6 cm. or more in diameter. Is it due to the tendency of the cavity to resume its original size as part of a sebaceous gland, or to the massaging action of pressure on the surrounding fat and aerolar tissue, or both? Perhaps with time and more experience these facts will finally be cleared. In the presence of an old scar to which the bottom or side of the cavity may have become fixed, dimpling occurs, resulting in a tubular final result (Fig. 2 j). While the first case was treated five years ago, there has been no known recurrence. Two patients have returned for the treatment of a second cyst having no relation to the first one. I feel that the cautery effect of the treatment is essential to producing the desired result and that simple knife excision of a button of tissue would not be so successful. I have not tried simple knife excision. There is probably nothing really new about either marsupialization or the use of a cauterizing agent for this purpose. I can imagine Hippocrates poking a hot iron into the center of a large sebaceous cyst and getting a fine result.

REFERENCE

- ¹ Danna, J. A.: A Simple Treatment for Sebaceous Cyst. *N. O. Med. & Surg. Jour.*, **98**, No. 1, 5, July, 1945.

DISCUSSION.—DR. A. B. MCGRAW, Detroit, Mich.: As I listened to this paper and looked at the lantern slides, it occurred to me that we should keep in mind the warning of the late Doctor Bloodgood, member of this Association, that especially in elderly patients these cysts are likely to be complicated by basal or squamous cell carcinoma. He advocated their complete extirpation. In connection with the difficulty of excising such cysts without rupture and extrusion of contents, the shaping of one's incision so as to include a very narrow ellipse of skin surrounding the epidermal attachment of the cyst and the use of that bit of skin as a handle, make it unnecessary that any instrument touch the thin wall of the cyst itself.

In conclusion, I have been coaxing myself all afternoon to have the temerity to discuss one other matter, connected with this meeting as a whole. There have been

many visitors here these past three days. On behalf of all of us who have been your guests I venture to express our sincere appreciation for the warmth of your hospitality and the stimulus of the presentations on this program; our admiration for the splendid military record of your Association throughout these four terrible years of war; and the added confidence we have gained from knowing that we share with such men as you the task of making the fragile peace into which we have emerged, a more enduring structure than the false millennium on which the world too naively embarked a quarter of a century ago.



ANNOUNCEMENT

THE EDWARD D. CHURCHILL LECTURE FOUNDED BY THE EXCELSIOR SURGICAL CLUB

A GROUP OF SURGEONS, who formerly served as members of the U. S. Armed Medical Corps in the North African and Mediterranean Theaters of Operations, recently organized The Excelsior Surgical Club. Patterned somewhat along the lines of the Eclat Club which, in a comparable manner, grew out of World War I, The Excelsior Surgical Club has as its objectives the promotion of the social intercourse of the members and the advancement of their knowledge of the science of surgery.

A principal and outstanding activity of the Club is to be the Edward D. Churchill Lecture honoring the former Surgical Consultant of those Theaters, Dr. Edward D. Churchill, John Homans Professor of Surgery at Harvard University. The Lecture, to which the medical public will be invited, will form an integral part of each annual meeting. The Club plans that each Lecture will be a foremost scientific presentation. To that end, Dr. Alfred Blalock, Professor of Surgery, Johns Hopkins University, has been secured to give the first Churchill Lecture at the first regular meeting of the Club in Boston on October 25-26, 1946.

MEMOIRS

ROBERT TUTTLE MORRIS, M.A., M.D., F.A.C.S.
1857-1945

ROBERT TUTTLE MORRIS, widely and affectionately known as "Bob Morris," was born at Seymour, Connecticut, May 14, 1857. The Morris genealogy extended from earliest colonial times. His father was a distinguished lawyer,



Robert Tuttle Morris

a Judge of the Probate Court and later Governor of Connecticut. The maternal side of his ancestry was equally distinguished, his mother, Eugenia Laura Tuttle Morris, being a well-known authoress.

Doctor Morris received a liberal education, with a strong admixture of the classical, at the Hopkins Grammar School at New Haven and later was engaged in biologic studies at Cornell University from 1875 to 1879. He was graduated

from the College of Physicians and Surgeons of New York in 1882, and became a member of the House Staff of Bellevue Hospital from 1882 to 1884. After his internship Dr. Morris studied in various surgical clinics in Europe and in 1884 met Lister in London, a visit that was to exert a profound influence upon his life work and provided the background and knowledge for his first book, "How We Treat Wounds Today," published in 1886. Doctor Morris was among the first to adopt Listerism and did much to awaken the profession to a new era in surgery. It is interesting to note that Lister visited the International Medical Congress in Philadelphia in 1876, the year Doctor Morris entered Cornell University. Somewhat later, in 1880, Samuel D. Gross—the Emperor of American Surgery—was to refer to Lister as "the famous reformer of the surgical treatment of wounds." Within ten years of Lister's visit to the United States and two years after a visit to Lister, Doctor Morris demonstrated a remarkable degree of surgical foresight and in his treatise clearly indicated the future acceptance of antiseptic surgery.

In 1889 Doctor Morris became Instructor in Surgery at the New York Post-Graduate Medical School and from 1898 until 1917 occupied a chair in Surgery and the position of attending surgeon in the Hospital. He was a brilliant speaker and a distinguished writer—two qualities that procured his early advancement and maintained his celebrity.

With the passing of time Doctor Morris' merits as a surgeon have tended to be obscured by his more facile gift for writing and by his great ability as a phrase maker. Yet, he was always a trained surgeon and enjoyed a large practice in an epoch of great individualism in surgery. His patients came from all parts of the United States and South America. Amongst his colleagues he was sometimes considered somewhat unorthodox in his surgical philosophy and pronouncements. It is safe to say, however, that many of his aphorisms will remain longer in the literature and memory of American surgery than his more substantial surgical contributions.

"The last living thing on earth will most certainly be a microbe."

"Toxic insignia left upon the peritoneum."

"Nine specialists to make one doctor."

"Cobwebs in the attic of the abdomen."

"The invalidism of the pelvic reflex."

These and many other surgical clichés had wide acceptance in his time and some are still current today.

Doctor Morris was always an interesting and impressive figure in the surgical clinic. His chief purpose was to arouse the attention of his students, to stimulate them to think. His case presentations were rarely logical expositions but rather entertaining and dramatic, interlarded with an abundance of surgical aphorisms. He used irony to arouse attention and had a sly and subtle wit. Sarcasm was not in his speech and he was always a worthy opponent in medical debate. Doctor Morris possessed in a singular degree serenity, urbanity, dignity and restless curiosity of mind. He was a fluent lecturer on widely diverse subjects; his spirit and his mind were attuned to the rapid evolution not only of medicine but also the cognate sciences.

He passed his professional career almost entirely at the Post-Graduate Hospital. He was a member of most of the national societies. He was admitted to membership in the American Association of Obstetricians and Gynecologists in 1890 and became President in 1907. He was elected a member of the Southern Surgical Association in 1900 and became a senior fellow in 1923. Doctor Morris was also President of the American Therapeutic Association in 1916, and was for many years President of the Physicians Home, Inc., of New York, for aged physicians.

After "fifty years a surgeon" Doctor Morris retired to his estate near Stamford, Connecticut, on his 440 acres of woodland where he spent his retirement in cross-grafting nut-producing trees. His place became a sanctuary for birds and wildlife. It is as an author that Doctor Morris will be chiefly remembered. Among the round dozen of his books were: "Lectures on Appendicitis," "Hopkins Pond," "Dawn of the Fourth Era in Surgery," "Tomorrow's Topics Series," "Microbes and Men," "A Surgeon's Philosophy," "Doctors Versus Folks," "The Way Out of War," "Nut-Growing," "Editorial Silence," and the last "Fifty Years a Surgeon."

There was a continuous curiosity in his mind associated with a persistent skepticism. There was an urbanity and equanimity in his intellect—always of high order. There was poetry in the dexterity of his hands and music in his heart, as is apparent in the last paragraph he wrote: "Bright sunshine lights the evening sky once more and high peaks glow, but soon long shadows steal down to darkening vales for night and deeper dark. 'Tis then I am a mountaineer, and yet at times, when all is still, I seem to hear loud surf—but that is only memory for one who loves the sea."

CHAS. GORDON HEYD, M.D.

ROBERT DUVAL JONES

1898-1945

It is with profound regret that I attempt to record the passing of Dr. Robert DuVal Jones, who was an able and conscientious surgeon and a member of the Southern Surgical Association.

Doctor Jones was born in New Bern, North Carolina, October 7, 1898, and died September 4, 1945. He was the son of Dr. Robert DuVal Jones of New Bern, North Carolina. He received his collegiate education at the University of North Carolina and graduated in medicine at the University of Pennsylvania in 1924. He served an internship at the Robert Packard Memorial Hospital, in Sayre, Pennsylvania. Following this he was a Surgical Fellow at the Mayo Clinic, where he was ably trained over a period of four and one-half years.

In January, 1930 he came to Norfolk, Virginia, and was my associate thirteen years. At this time in his career he sustained a severe coronary occlusion and remained bedridden about ten months. His recovery from this cardiac catastrophe was most satisfactory and he returned to Norfolk to engage in private practice of surgery, where he was active and during the great stress of war and the shortage of surgeons, he accomplished professional undertakings that were a great strain and hazard on his physical reserve. In August, 1945, while on a vacation in the mountains of North Carolina, he underwent another severe coronary occlusion which resulted in his death ten days later.



Robert DuVal Jones

Something of his devotion to his profession, one suspects, played a part in his determination, after earlier ill health, to return to as much practice as he could handle under conditions which required that he take unusually good care of himself but when the abilities of men like him were badly needed in a community which temporarily lost many of its physicians to the war needs. He was too intelligent not to know the risk, but it seems probable that he would not have been content with doing anything less than his utmost in the circumstances and that he felt he must go ahead with the surgery for which he was admirably prepared.

The death of such a man, at an age when he is in the full stride of his career, and when both he and the people among whom he lived can ordinarily look forward to many years of usefulness, is peculiarly tragic. He might have had much ahead of him. Those who knew Doctor Jones best have the added loss of a man of fine feeling, of keen taste and discrimination for the subjects which interested him outside his work, and of a friendly courtesy which made him an unusually pleasant companion.

R. L. PAYNE, M. D.

GERRY ROUNDS HOLDEN

1874-1945

A NATIVE of Concord, N. H., Dr. Gerry R. Holden spent the years before settling in Florida securing a thorough preparation for the work which he was to carry on for four decades in his adopted state. After graduating from Yale University in 1897, he entered the Johns Hopkins Medical School and received the degree of Doctor of Medicine in 1901. Immediately thereafter he studied in Berlin for several months before beginning his hospital training at the Roosevelt Hospital in New York. When he had completed the service there, he became a member of the Gynecologic House Staff of the Johns Hopkins Hospital at Baltimore, where he served as resident.

In 1905, when Dr. Holden located in Jacksonville, Fla., the facilities for practicing medicine in the state, so new to him, were not far from primitive in comparison to those of the clinics in which he had been working. In his chosen profession of gynecology he became truly a pioneer in Florida.

Soon after his arrival his good influence on hospital staffs began to be felt. Within a year, he was a member of the staff of St. Luke's Hospital in Jacksonville and also of the staff of the State Hospital for the mentally ill at Chattahoochee. As the years went by, he became gynecologist for the Duval County Hospital and consultant for the Riverside Hospital in Jacksonville, and consultant for the Flagler Hospital in St. Augustine.

When Dr. Holden returned home from military service in World War I, the possibilities of the use of radium in the treatment of gynecologic conditions so appealed to him that he prepared himself and obtained the equipment for treatment with radium. For the last twenty-five years of his life, his practice was restricted almost wholly to this line of work. While carrying on a very active practice, he presented before local, state and sectional societies many valuable papers based upon a broad and long-continued experience in the use of radium.

During the later years of his life especially, there was hardly a movement for the betterment of medicine in his state in which Dr. Holden did not have an active and outstanding part. At one time, he was President of the Duval

County Medical Society, the Florida Medical Association and the Southeastern Surgical Congress. As a founder Fellow of the American College of Surgeons, he appreciated the worth of the standards set by this organization. From the very beginning he was constantly active in the affairs of the College. He was also a Fellow of the American Medical Association and a member of the Southern Medical Association, the Southern Surgical Association and the South Atlantic Association of Obstetrics and Gynecology. He was held in the



Gerry Rounds Holden

highest esteem by the profession, and his friends among its members were legion.

Revered alike by the laity, Dr. Holden not only engaged in his many medical activities but also devoted much time to the work of his church. He served for thirty years as an official member of the Riverside Presbyterian Church of Jacksonville and twice was a delegate to the General Assembly of the Presbyterian Church at Montreat, N. C.

He is survived by his widow, Mrs. Anne Millikens Holden, and one daughter, Miss Katherine Holden, of Jacksonville, and one son, Gerry R. Holden, Jr., and two grandchildren, of Hartford, Conn.

EDWARD JELKS, M. D.

WILLIAM FARQUHAR SHALLENBERGER

1881—1944

IN THE passing of Dr. William Farquhar Shallenberger the Southern Surgical Association lost a most valuable and beloved member. His death occurred at the Piedmont Hospital in Atlanta, on December 16, 1944, after a



William Farquhar Shallenberger

brief illness. However, his health had been such that he had given up active practice five and a half years previously. His widow, Mrs. Laura Boyd Shallenberger, died April 2, 1946. He is survived by a daughter, Mrs. A. E. Gossett.

Dr. Shallenberger was born in Greensburg, Pennsylvania, on July 25, 1881, the son of the late Frank and Emma Shallenberger. He was graduated A.B. from Washington and Jefferson College in Pennsylvania, in 1903. The following year he matriculated in the Medical School of Johns Hopkins University, from which he graduated with honor in the class of 1907. Upon graduation he was given an appointment as intern in the Johns Hopkins Hospital. On the staff at the time were such notables as Drs. Howard A. Kelly, Thomas S. Cullen, Guy L. Hunner, J. Whitridge Williams, W. H. Welch, W. S. Halsted and William Osler. It was Dr. Shallenberger's good fortune to have

studied under these outstanding physicians and their teachings had a great and lasting influence on his professional life. After completing several years as intern at Hopkins he became resident gynecologist in the Woman's Hospital, in Baltimore, where he served two years.

In 1911, he came to Atlanta to locate and entered into the practice of gynecology, obstetrics and abdominal surgery. He soon established an enviable reputation in this specialty and rapidly built up a large practice. As a disciple of Drs. Kelly and Hunner he was among the first in this section to emphasize female urology in gynecology. In 1913, he married Miss Laura Boyd, of Savannah, a sister of his friend and classmate, Dr. Montague L. Boyd, urologist of Atlanta.

Shortly after locating in Atlanta, Dr. Shallenberger became actively associated with the Piedmont Hospital where he did the great majority of his work. He gave much of his time and talent toward raising the standards of this institution and until his retirement was Chief of the Obstetrical and Gynecological Service there. He was Associate Professor of Gynecology in the Emory University Medical School for many years. Later he resigned this position and became Chief of the Department of Obstetrics and Gynecology at the Grady Hospital, white unit. He loved the association of the interns and younger men and gave unstintingly of his time and energy in these teaching positions. He was a member of the Fulton County Medical Society, Medical Association of Georgia, American Medical Association, Southern Medical Association, Southern Surgical Association, Southern Interurban Gynecological and Obstetrical Society and a Fellow of the American College of Surgeons. He belonged to Phi Delta Theta, Alpha Omega Alpha, and was an honorary member of the Alpha Kappa Kappa medical fraternity. He wrote several valuable papers on gynecologic and urologic subjects. He was a member of the First Presbyterian Church, in Atlanta, and also held memberships in the Capital City Club and Piedmont Driving Club.

After his forced retirement from active practice, Dr. Shallenberger refused to remain idle and during the crisis of war worked daily at the office of the Rationing Board, a position without remuneration and requiring much time and energy. He will be remembered by those who knew him best as not only a capable surgeon, but as a refined, cultured gentleman who had great courage and determination and a high devotion to the ideals of his profession.

FRANK K. BOLAND, M.D.

EDITORIAL ADDRESS

Original typed manuscripts and illustrations submitted to this Journal should be forwarded prepaid, at the author's risk, to the Chairman of the Editorial Board of the ANNALS OF SURGERY.

Walter Estell Lee, M.D.
1833 Pine Street, Philadelphia, Pa.

Contributions in a foreign language when accepted will be translated and published in English.

Exchanges and Books for Review should be sent to James T. Pilcher, M.D., Managing Editor, 121 Gates Avenue, Brooklyn, N. Y.

Subscriptions, advertising and all business communications should be addressed

ANNALS OF SURGERY

East Washington Square, Philadelphia, Pa.